

Issued November 18, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

FOREST SERVICE—BULLETIN 98.

HENRY S. GRAVES, Forester.

REFORESTATION ON THE NATIONAL FORESTS.

PART I.—COLLECTION OF SEED.

PART II.—DIRECT SEEDING.

BY

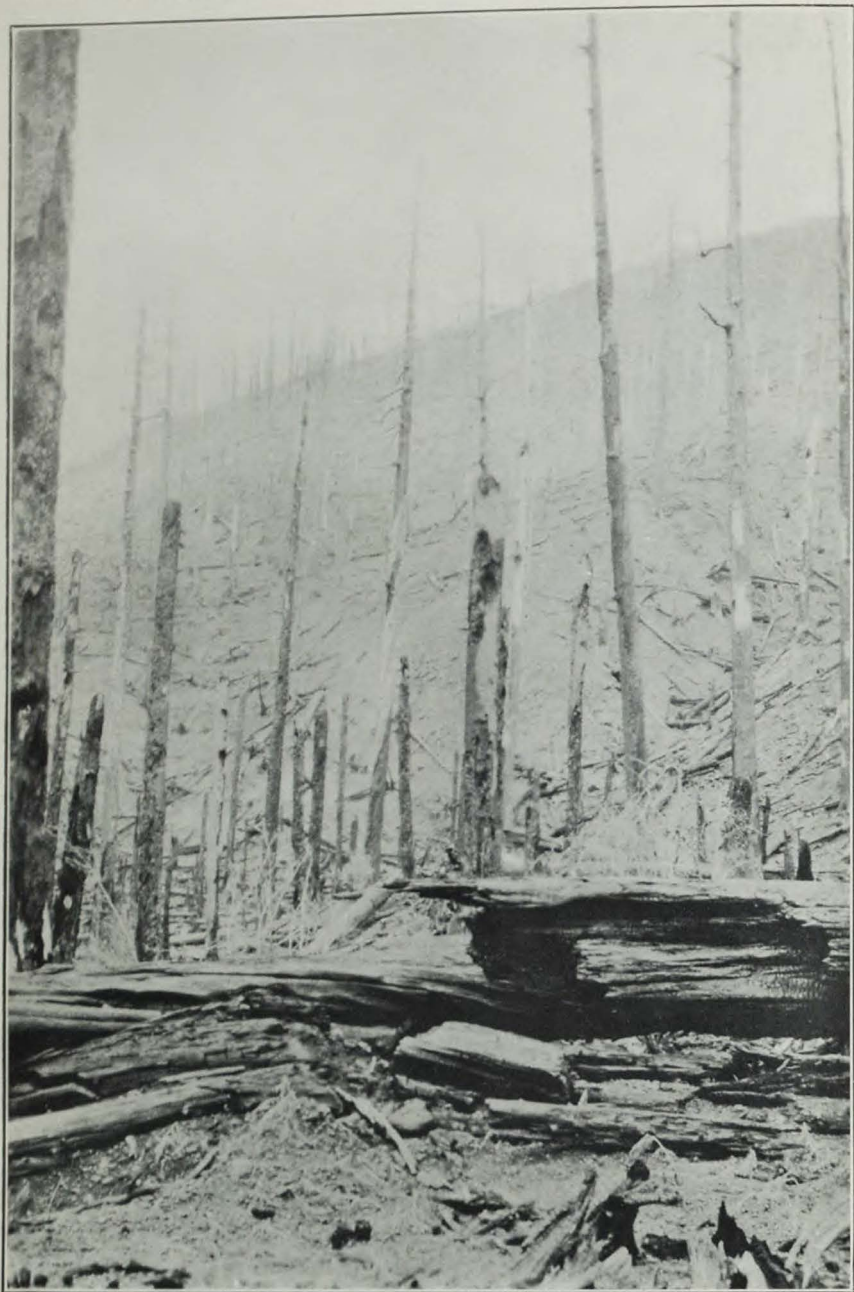
WILLIAM T. COX,

ASSISTANT FORESTER.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1911.



AREA IN NEED OF REFORESTATION, OLYMPIC NATIONAL FOREST.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,

Washington, D. C., March 24, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "Reforestation on the National Forests: Part I—Collection of Seed; Part II—Direct Seeding," by William T. Cox, Assistant Forester, and to recommend its publication as Bulletin 98 of the Forest Service.

Respectfully,

HENRY S. GRAVES, *Forester.*

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Waste land which will produce timber.....	7
Present conditions on the National Forests.....	7
Natural reproduction.....	8
Artificial reproduction.....	9
Experiments.....	12

PART I.—COLLECTION OF SEED.

Seed crops.....	13
Gathering the seed.....	16
Cost of seed gathering.....	18
Extracting the seed.....	19
Testing the seed.....	23
Seed-testing laboratory.....	23
Yield from cones.....	23
Number of seeds per pound.....	24
Percentage of germination.....	24
Methods of storage.....	25

PART II.—DIRECT SEEDING.

Direct seeding <i>versus</i> planting.....	29
Past work on the National Forests.....	29
Selection of the site.....	30
Time of year for seeding.....	30
Broadcasting.....	32
Sowing in strips and blocks.....	33
Seed spots.....	34
Quantity of seed per acre.....	35
Protection from rodents.....	36
Protection from stock and fire.....	39
Cost of sowing.....	39
Instances of successful direct seeding.....	42
Olympic National Forest.....	42
Oregon National Forest.....	43
Siuslaw National Forest.....	44
Manzano National Forest.....	46
Minidoka National Forest.....	46
Uinta National Forest.....	46
Bitterroot National Forest.....	47
White River National Forest.....	47
Black Hills National Forest.....	48
Sequoia National Forest.....	48
Trinity National Forest.....	48
APPENDIX—Notes on individual species.....	51
Austrian pine.....	51
Bigtree.....	51
Black walnut.....	52

APPENDIX—Notes on individual species—Continued.

	Page.
Cork oak.....	52
Douglas fir.....	52
Engelmann spruce.....	53
Eucalypts.....	53
European larch.....	53
The hickories.....	53
Lodgepole pine.....	54
Norway spruce.....	54
Red oak.....	54
Red pine.....	55
Scotch pine.....	55
Sitka spruce.....	55
Sugar pine.....	55
Western larch.....	56
Western white pine.....	56
Western red cedar.....	56
Western yellow pine.....	57
White oak.....	57
White pine.....	57

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Burned area in need of reforestation	Frontispiece.
II. Fig. 1—Site of forest ruined by destructive lumbering and fire. Fig. 2—Five-year-old stand of western yellow pine, result of direct seeding	8
III. Fig. 1—Drying and opening western yellow-pine cones. Fig. 2— Interior of drying room	16
IV. Fig. 1—Cone shaker. Fig. 2—Shaking cones a second time and burn- ing them	24
V. Fig. 1—Seed-fanning mill. Fig. 2—Cones of western yellow pine being run through a steam grain separator	24
VI. Fig. 1—Direct seeding of Douglas fir. Fig. 2—Seed-spot sowing	32
VII. Four common rodents destructive to tree seed	36

TEXT FIGURES.

FIG. 1. Range of Douglas fir, and areas of seed crop, 1909 and 1910	14
2. Range of western yellow pine, and areas of seed crop, 1909 and 1910 ...	15
3. Plan of seed-drying house	21
4. Mount Hebo, showing area sown, Siuslaw National Forest	45
5. Custer Peak Experimental Area No. 1, Black Hills National Forest	49

REFORESTATION ON THE NATIONAL FORESTS.

WASTE LAND WHICH WILL PRODUCE TIMBER.

It is assumed that the American people do not want to see land lying idle. There are many millions of acres of untillable mountain land and dry, sandy tracts, now utterly unproductive, which can and should be made to produce timber. Much of this area consists of cut-over and burned-over land in the South and in the eastern mountains, while much more is logged-off land in the Lake States. A considerable part, however, lies in the National Forests of the West.

Next in importance to protecting the National Forests from fire and disposing of the mature timber in a way to secure good, natural reproduction is the task of starting forest growth upon the vast areas of untillable mountain lands which have been rendered unproductive by fires, insects, and other agencies. The Forest Service has taken up in earnest this enormous task.

The subject of artificial reforestation on the National Forests divides itself naturally into three parts—collection of seed, direct seeding, and planting of seedlings. The two first are discussed in this bulletin; the third will be treated separately in a later bulletin of the Forest Service. Before describing the actual work of reforestation, however, it is necessary to present a general view of the present conditions on the National Forests and of the policy of the Forest Service with regard to the reforestation of denuded areas.

PRESENT CONDITIONS ON THE NATIONAL FORESTS.

The National Forests embrace an area of 191,548,000 acres, scattered from Alaska to Porto Rico. Within their boundaries are found portions of the jack-pine barrens of Michigan, the sandhills of Nebraska, the western yellow pine of the Southwest, the stunted chaparral forests of southern California, the subtropical hardwoods of the West Indies, the great lodgepole pine and spruce protective forests of the Rocky Mountains, and the splendid fir and cedar of the north Pacific coast. They contain every grade of timber from stands

NOTE.—The writer desires to make acknowledgment of valuable assistance given him by Mr. Raphael Zon, Mr. J. M. Fetherolf, Mr. Fred Ames, and other members of the Forest Service in the preparation of this bulletin.

which will produce only cordwood to some of the finest and most valuable forests in the world. Hundreds of species of trees grow under the conditions presented by almost every kind of soil and climate.

From the best information available an effort has been made to classify the lands within the National Forests. The figures given, though necessarily approximate, fairly represent existing conditions. Of utterly barren land there are within the National Forests approximately 15,000,000 acres. This consists of 4,000,000 acres of rocks, cliffs, and arroyos, and 11,000,000 acres of unproductive land above timber line. Of open grass land, there are 16,000,000 acres; of mature timber, 60,000,000 acres; and of young tree growth, 40,000,000 acres. But of chief interest is the denuded and otherwise unproductive land capable of growing trees, which at present is either bare or covered with brush or other worthless growth. This aggregates about 15,000,000 acres, of which approximately one-half will, under proper management, reforest naturally within a reasonable time, leaving 7,500,000 acres which must be artificially sown or planted. This is not all. When natural regeneration fails, as in blanks, or where a forest not yet producing seed needs to be increased in density, or where some species is to be replaced by a better one, and this can not be done by natural reproduction, artificial reforestation must step in.

The task of reforesting this enormous area is rendered still more difficult by the complexity of the problem. Much of the experience gained in tree planting in the East or on the prairies of the Middle West has proved useless or misleading in establishing tree growth in the high watersheds of the Rocky Mountains, the semiarid ranges of the Great Basin, and the parched foothills of California. The greater portion of the area which it seems advisable to reforest consists of old burns, where recurring fires have completely ruined the former forest, leaving a scanty, sterile, and dried-out soil, often littered with charred down timber and stumps. Some of these areas have grown up to brush, some to fern, and some to grass and fireweed. Many have been eroded to such an extent that it is doubtful if they can ever be made to bear trees again, while there are large areas where all the vegetable soil has been burned. Among the easiest to reforest are those which have recently suffered from light fires, so that the mineral soil is exposed, but which are not so badly eroded or grown up to brush as to prevent tree seed from germinating.

NATURAL REPRODUCTION.

Approximately 90,000 acres within the National Forests are being cut over each year in the course of timber sales. Some of this is cut clean, but much is only partly cleared. Practically all of this



FIG. 1.—FOREST RUINED BY DESTRUCTIVE LUMBERING AND FIRE.

Artificial reforestation necessary to bring the tract into productive condition within a reasonable time.



FIG. 2.—FIVE-YEAR-OLD STAND OF WESTERN YELLOW PINE, RESULT OF DIRECT SEEDING, BLACK HILLS NATIONAL FOREST.

Average height of trees, 12 inches. Soil unprepared before sowing; cover consisted of small scrub aspen and weeds; area severely burned several years previous.

area reforests naturally, because of the manner in which the cutting is required to be done. Under ordinary methods of logging this 90,000 acres a year would be added to the area of waste land. Under the system of cutting prescribed for the National Forests the character of the forest is improved and an increased yield per acre is gotten from the next crop. The possibilities in this respect are almost startling. It is seldom that nature unaided produces a full-stocked stand of timber, just as it is rare to find a volunteer crop of grain equal to that of a well-tended field. There are thin spots and blanks all through the untended forest. At present the average yield per acre of timber on the National Forests is in the neighborhood of 4,000 feet. This undoubtedly can be increased four or five times, perhaps more.

Before the lands constituting the National Forests were put under administration, fires ran through the woods uncontrolled, burning over large areas each year. Sometimes great belts of virgin timber were killed; more often the young growth was destroyed. The system of fire patrol, inaugurated by the Forest Service, while admittedly inadequate through lack of funds, has nevertheless gone far toward stopping this heavy annual loss and has given much of the old burned-over land the opportunity to come up to young trees again. From observation and from data collected upon the National Forests, it is safe to assume that by keeping out forest fires, even to the extent that has been possible with one patrolman to 100,000 acres, natural reforestation is taking place in the small treeless openings at the rate of at least 150,000 acres a year. Overgrazing, especially by close-herded sheep, formerly prevented natural reproduction of timber upon large areas in certain types of forests. Not only did the sheep injure the young seedlings directly by grazing and trampling, but they did even greater damage through destroying the ground cover, exposing the soil to erosion, and subjecting it to the drying effects of wind and sun. The same effect has followed the excessive grazing of cattle, horses, and goats, where these were allowed to concentrate around watering places or salting grounds. Under such conditions it is difficult for tree seed to germinate, and still more difficult for the tiny seedlings to grow. Grazing of all kinds of stock within the National Forests is, under certain conditions, both desirable and beneficial, but careful regulation of the grazing and temporary exclusion of stock from certain overgrazed districts has done much toward making it possible to obtain both natural and artificial reproduction.

ARTIFICIAL REPRODUCTION.

The policy of the Forest Service in artificial reforestation on the National Forests is, first, to conduct experiments to find out what can be done and what is the best way to do it; second, to reforest by direct seeding wherever this is feasible; and, third, to plant nursery seedlings where direct seeding is too uncertain. In selecting sites for artificial reforestation preference is usually given in the following order: First, watersheds of streams important for irrigation and municipal water supply; second, lands which produce heavy stands of quick-growing trees; third, lands suitable for the production of especially valuable species, and where conditions are favorable for improving the character of the forest; fourth, sites which offer good opportunities for object lessons to the public in the practice of forestry; fifth, denuded lands which have no special claim for attention, except that they will grow some kind of trees.

Some areas offer combinations of advantages. For instance, a burned-over tract may be suitable for sowing to some rapid-growing species which is also valuable for timber, and may be so situated that it will serve as an object lesson as well. It is upon such areas in general that reforestation is being concentrated.

In the work more attention should be given to mountain forests of spruce, fir, and lodgepole pine than to the lower and more open forests of yellow pine, because yellow pine is not as valuable for protective purposes as some of the other species, nor does it yield so heavily per acre. Moreover, the yellow-pine belt usually occupies the lower, drier portions of the mountains, where conditions are comparatively unfavorable for sowing or planting. Reforestation should be undertaken on a much larger scale in the Northwest than elsewhere, because conditions are favorable not only for reestablishing forests where they have been destroyed, but also for rapid growth after they are established. A given amount of money will reforest a larger area in Washington, Oregon, and Idaho than in the Rocky Mountains, and the resulting forest will produce valuable timber more quickly.

That under certain conditions it is highly profitable to reforest waste lands in the National Forests is not to be questioned. In calculating returns through a long period of years, however, as it is necessary to do in forestry, several unknown quantities enter, which at the present time can only be estimated. The chief of these is stumpage values; that is, what prices can be obtained for timber in 50, 60, or 70 years, when it is ready to be cut. From present indications and the records of past years it is safe to assume that as long as timber prices rise stumpage prices are certain to increase, and that after timber prices have reached their maximum stumpage will continue to increase up to the cost of production, the lumberman

operating at a less percentage of profit than at present. It is necessary, therefore, in figuring on the probable returns from forest plantations, to assume higher stumpage prices than are now being paid, particularly in the far West. Second-growth white pine, for instance, now sells for from \$6 to \$10 per thousand board feet on the stump, while old virgin growth readily commands a price of \$14 per thousand. On the National Forests it is not necessary to figure the value of the land or taxes into the investment, since the land already belongs to the Government and remains its property after the timber is cut. The cost of establishing forest growth, and its subsequent care and protection, are all that need to be reckoned with.

From actual experiments made it is estimated that a white-pine forest artificially established on second-class forest soil, in Minnesota, will yield 46,500 board feet per acre in 50 years, worth at least \$10 per thousand, or \$465 per acre. Figuring the cost of planting at \$7 per acre and the cost of care and protection at 3 cents per acre per year, and reckoning both at 3 per cent compound interest, gives a total cost of \$34.07 per acre at the time the timber is cut and a net profit per acre at the end of 50 years of \$430.93.

From red pine, which is native to Minnesota and the Lake region, approximately similar returns may be expected. This tree, moreover, can be planted on poorer soil than white pine, though it is probable that where this was done the yield would be slightly less.

With Douglas fir in the Northwest it is conservative to assume that the timber will be worth \$6 per thousand feet on the stump 50 years from now, and that it will increase in price 50 cents every decade thereafter for perhaps 50 years, making its stumpage value a hundred years from now \$8.50 per thousand. Douglas fir, if as closely utilized as the white pine cited, namely, to a top diameter of 4 inches, should yield per acre in 50 years 47,000 board feet; in 60 years, 58,000 board feet; in 70 years, 70,000 board feet; in 80 years, 81,000 board feet; in 90 years, 91,000 board feet; and in 100 years, 103,000 board feet. These yields are somewhat higher than at present are obtained, but it is reasonable to assume that within the next 50 years Douglas fir will be as closely utilized as white pine is now. Using the above figures for stumpage and yield gives gross profits of \$282, \$377, \$490, \$607.50, \$728, and \$875.50, respectively. Douglas fir can be sown direct at a less cost than if seedlings were planted. Placing the cost of seeding at \$4 per acre and protection at 3 cents per acre per year, and figuring both at 3 per cent compound interest, gives a net profit at the end of 50 years of \$261.08; at the end of 60 years of \$348.54; at the end of 70 years of \$451.41; and at the end of 80 years of \$555.30. It must be remembered in all these calculations that the money invested is earning interest at 3 per cent, and that the net profits given are earnings in excess of this 3 per cent interest.

Sitka spruce is another species especially adapted to the humid coast regions of Washington and Oregon. It is more exacting in its soil and moisture conditions than Douglas fir, but grows almost as rapidly and does well both in pure stands and in mixture with other species. The tree attains large size and produces heavy stands of good timber, but probably will yield slightly less than Douglas fir. The cost of establishing Sitka spruce artificially, however, is comparatively small, and the money returns will almost equal those from Douglas fir.

EXPERIMENTS.

Experiments in reforestation are being conducted by the Forest Service in the field by the regular Forest force and at well-equipped forest experiment stations by specially trained men. The experiments are always conducted with the definite object of proving at least one thing conclusively. During the fiscal year 1910 over 800 experiments in artificial reforestation were conducted upon the National Forests, in which 60 species were used. Such questions as how is the vitality of seed influenced by the locality in which collected, by altitude, exposure, age, and health of seed trees; under what conditions is the preparation of the ground advantageous in direct seeding; what is the best method of preparation; what is the best method of sowing; how much seed is required; what is the best method of protecting seed from rodents and birds; and what is the best season of the year for sowing, were wholly or in part solved.

PART I.—COLLECTION OF SEED.

SEED CROPS.

All planting and sowing on the National Forests must begin with the collection of seed. Trees, unlike some other plants, do not bear a good crop of seed every year. Conifers in particular are very irregular in the matter of seed production. A few cones are produced every year, but it is only at intervals of from two to five years, or more, varying with the species and the climatic conditions, that a heavy crop occurs. Years when seed of any species is produced in abundance are known for that species as "seed years," while the intervening years are called "off years." During "off years" not only is seed produced in small quantities, but because of the concentrated demand for it by rodents and birds it is difficult to obtain. Insect damage to the cones and to the seed itself is also concentrated, so that a small crop is likely to be one of low quality as well.

Usually a "seed year" for any species means an abundant crop of seed throughout most of its range, though much better in some places than in others. Even during an "off year," however, a species may produce somewhere within its range a fair crop over a limited territory.

Studies made to determine what constitutes a good crop for different species have given the following interesting figures:

TABLE 1.—Amount of seed per acre produced by different species.

Species.	Trees per acre bearing seed in appreciable quantities.	Bushels of cones per tree.	Pounds of seed per bushel of cones.	Pounds of seed per acre.
Douglas fir.....	10	3.50	1.25	43.75
Yellow pine.....	5	4.00	1.50	30.00
Lodgepole pine.....	40	.50	.25	4.00
White pine.....	7	1.00	1.10	7.70
Red pine.....	5	.80	1.00	4.00
Engelmann spruce.....	12	1.25	.80	12.00
Sugar pine.....	8	7.00	1.60	¹ 89.60

¹ The sugar pine is a large-seeded species, so that this weight of seed does not indicate a greater number of seed per acre than is produced by some of the other species.

The season of 1910 was an "off year" for both Douglas fir and western yellow pine, the two most important trees of the West, yet cones of sufficient quantity were collected in widely separated localities to furnish 30 tons of clean seeds of these species. The year was

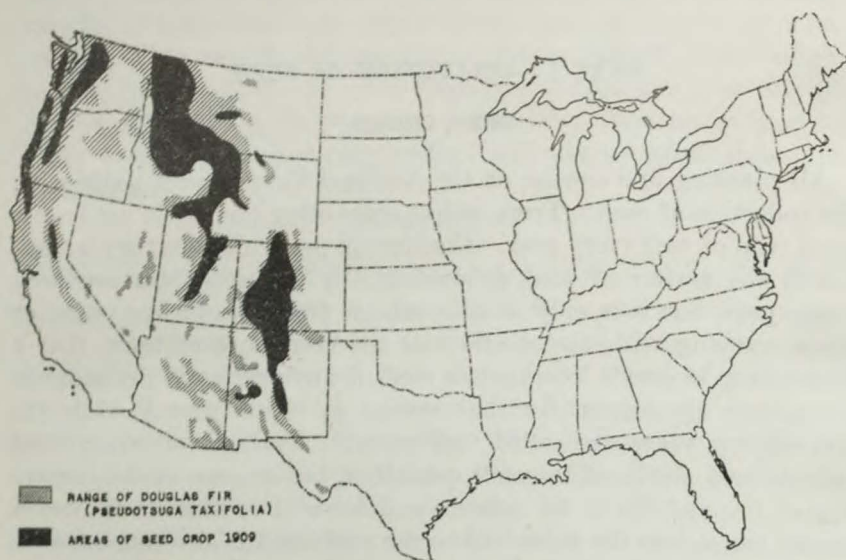


FIG. 1A.—Range of Douglas fir, and areas of seed crop, 1909.

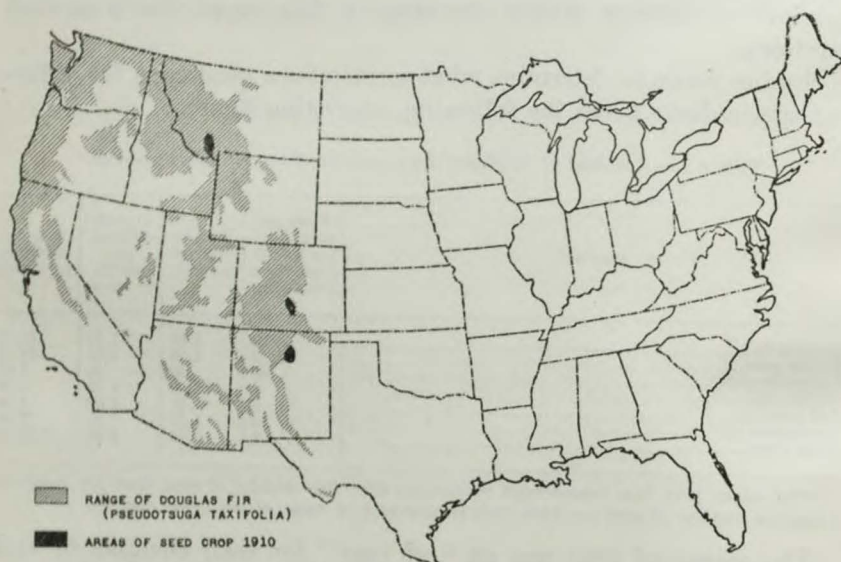


FIG. 1B.—Range of Douglas fir, and areas of seed crop, 1910.

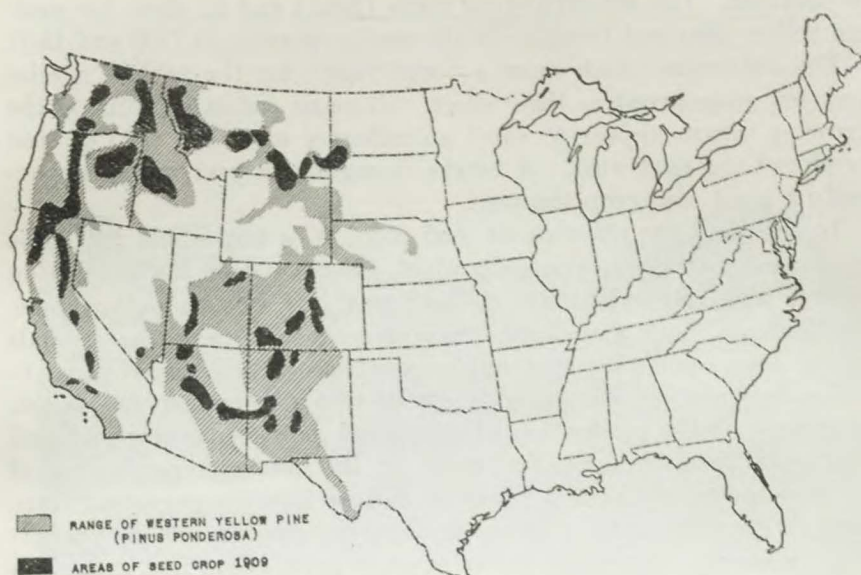


FIG. 2A.—Range of western yellow pine, and areas of seed crop, 1909.

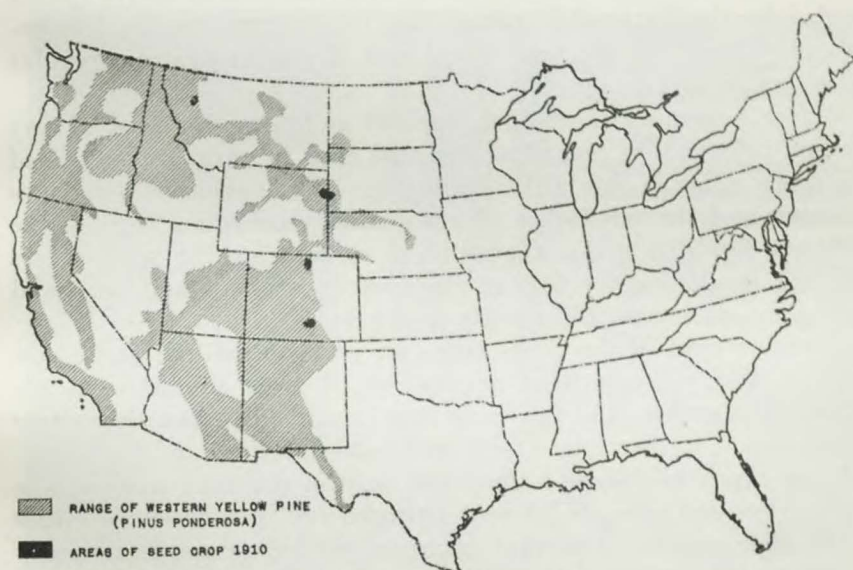


FIG. 2B.—Range of western yellow pine, and areas of seed crop, 1910.

also an "off" one for Engelmann spruce, western white pine, and white pine, and comparatively small quantities of these seeds could be obtained. The accompanying maps (figs. 1 and 2) show for western yellow pine and Douglas fir the seed-crop areas in 1909 and 1910.

The influences which cause a "seed year" for the various species are very widespread in their effect. Climatic conditions during the growing season appear to exert an influence upon the crop of seed produced the next year. A severe drought one year means apparently a good seed crop the next.

In studying the question of seed crops it is impossible not to be impressed with the relationship which exists between the production of tree seed and rodent life in the forest. If western yellow pine, for instance, bore a uniform crop of seed each year, the animals which feed upon this seed might soon become so numerous as to seriously endanger the existence of the tree as a part of the forest. It is only by the production of occasional or periodic crops of seed that conditions are made favorable for the natural reproduction of the tree species. There is reason to believe that the persistent trapping of the pine marten, which feeds upon squirrels, has, by permitting an abnormal increase in the squirrel population, had an appreciable effect upon tree reproduction in certain places.

GATHERING THE SEED.

The Forest Service itself collects most of the seed of native species needed for the National Forests. This can be done usually for considerably less than the seed would cost if purchased from regular collectors or seed dealers.

Before beginning the actual work of collecting the seed of any species, information regarding the seed crop in various portions of the tree's range is obtained. Knowledge of the relative abundance of cones and the possibility of economically collecting seed in the different localities make it possible to concentrate the work where the best results can be had at the least expense. Small, scattered operations, of course, add greatly to the cost.

Cones of most of the pines take two years to mature, and a few require three years, so that a crop can often be predicted in advance. The spruces and firs, including Douglas fir, ripen their cones in one season, as do western larch and western red cedar.

Cones ripen at different times not only in different parts of the tree's range, but even at different altitudes and in different localities in the same region. A careful examination of the cones is necessary in order to determine when collecting should begin. The external appearance of the cone is not a sufficient indication of the condition of the seed, but a number of cones should be cut open and the seeds themselves examined. This can readily be done by cutting off the

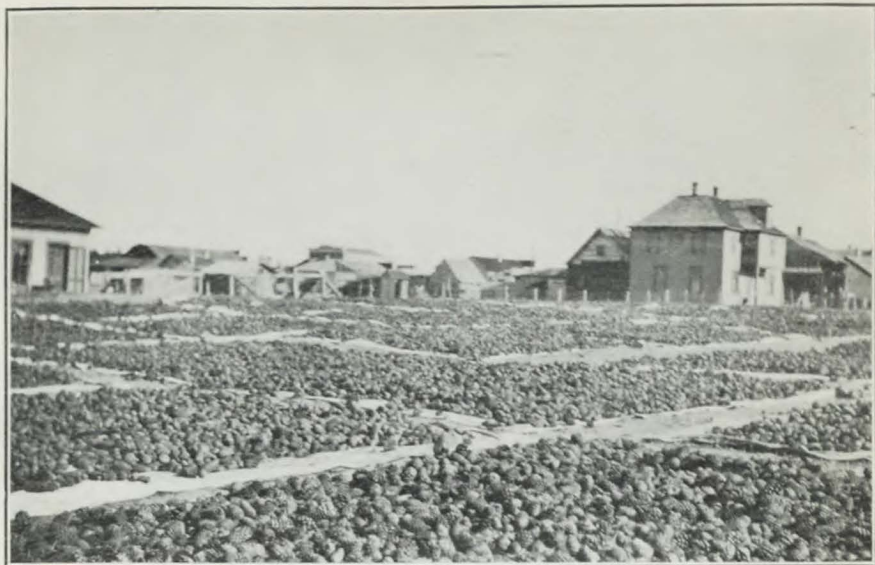


FIG. 1.—DRYING AND OPENING WESTERN YELLOW PINE CONES, BLACK HILLS NATIONAL FOREST.

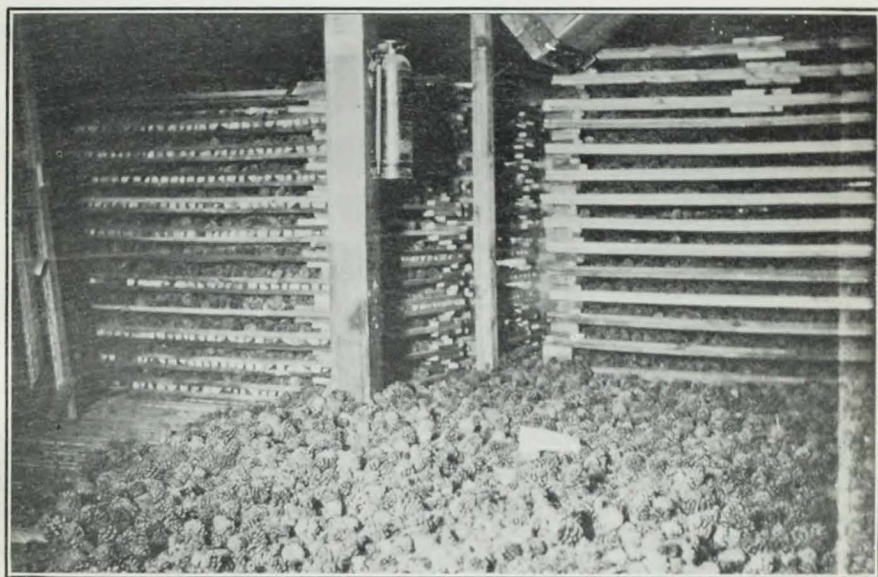


FIG. 2.—INTERIOR OF DRYING ROOM, SHOWING ARRANGEMENT OF TRAYS.

scales with a sharp knife in the direction of the apex of the cone. As long as the seed is soft and milky it is immature. When the squirrels begin to cut off cones for storing collecting should begin at once. For most species the period for collecting the cones is short if they are taken directly from the trees. Hard frosts, followed by warm days, hasten the ripening and opening of cones, and when once begun, collection should be prosecuted with all possible haste.

There are three methods of collecting cones—from felled trees, from standing trees, and from squirrel hoards. Where logging is going on it is often possible to pick the cones from the felled trees and from the ground after the brush is piled. This is a very economical method for some of the hard-coned species, provided the logging operations are extensive and a large number of trees are felled each day. In collecting from standing trees it may or may not be necessary to climb. Cones can often be stripped from short-limbed trees by cone hooks fastened to poles, or can even be picked off by hand. When climbing is necessary the cones are stripped or picked off by hand or by means of short hooks. It is best to begin work at the top of the tree, since then the cones can more easily be seen. Occasionally it is advisable to cut down heavily fruited trees, but this should be done only when the tree itself can be utilized.

Squirrels' caches are often excellent places from which to get cones. Pine squirrels collect and store large quantities, while chipmunks, and even mice, lay by stores. These rodents do not put by seed for the winter only, but continue to collect as long as the supply lasts and the weather permits. In consequence, they frequently lay by quantities out of proportion to their need. The small red squirrels are the greatest collectors of all, and it is not uncommon to find in a single one of their caches from 8 to 12 bushels of good cones, though the average quantity is about 2 bushels. These caches are located by old rotten logs, in springy places and muck, and in duff, sometimes at a considerable depth, as well as under bushes and felled tree tops, along streams, and beneath overhanging stream banks. Their presence is evidenced by heaps of cone scales and chips where the squirrels have been feeding. Sometimes the caches are carefully covered with leaves and humus, making it difficult to locate them, though the squirrels' well-beaten trails often guide the collector. The squirrels do not confine their collecting to a few species, but appear to relish a large number. Among the species of cones which are often obtained from caches are Douglas fir, Engelmann spruce, western yellow pine, lodgepole pine, and western white pine. Usually, however, the cones of but one species are found in a single cache. In collecting from squirrels' hoards it is well to have a pack horse along for immediate transportation, since if cones are dug out and left on the ground for any length of time

they will be carried away and cached again by the industrious animals.

Collecting from squirrel hoards has two important advantages over the other methods, in that it can be carried on after the cones on the trees are open, while at the same time a high grade of cones is obtained. In one instance 610 bushels of lodgepole pine cones were collected from squirrel caches on the Targhee National Forest, at an average cost of 18 cents a bushel, one man collecting 16½ bushels a day. During the fall of 1908, 1,137 bushels of yellow-pine cones were collected from caches on the Boise National Forest after the cones on the trees had opened. During the early part of October, 1910, a collection of lodgepole pine cones was made from squirrel caches on the North Fork of the Shoshone River, Wyo. The average quantity of cones found in each hoard was 2 bushels, and the maximum in one hoard 7 bushels. Ranger labor was used entirely, and pack horses brought the cones to camp as soon as gathered. The cost per bushel for gathering and hauling to headquarters, a distance of 23 miles, was 60 cents.

With those cones which open rapidly, care must be taken to put them in a damp place as soon as picked, so that they will not open and allow the seed to escape before the work of extraction begins.

COST OF SEED GATHERING.

During the autumn of 1910 the Forest Service collected 107,780 pounds of native tree seed and purchased 54,100 pounds of the seed of European species, a total of 161,880 pounds. The average cost per pound of that gathered by the Forest Service in 1909 and 1910 is shown by species in the following list:

Douglas fir	\$1.20	Jeffrey pine	\$0.50
Yellow pine	.80	Sugar pine	.85
Lodgepole pine	4.00	Coulter pine	1.50
Engelmann spruce	3.00	Incense cedar	1.20
Western white pine	1.25	Western red cedar	2.00

Yellow-pine seed has been collected by the Forest Service for much less than 80 cents a pound during good seed years for the species. With the improved methods employed in seed collection, it is reasonable to expect that the cost of collecting tree seed of all kinds will be greatly reduced within the next year or two. Table 2 shows the average price per pound asked by seed dealers.

TABLE 2.—*Kind of seed and price per pound.*

Species.	Price per pound.
Douglas fir (<i>Pseudotsuga taxifolia</i>).....	\$1.85 to \$3.25
Western yellow pine (<i>Pinus ponderosa</i>).....	1.00 to 2.25
Engelmann spruce (<i>Picea engelmanni</i>).....	2.75 to 4.25
Sugar pine (<i>Pinus lambertiana</i>).....	1.25 to 2.25
Jeffrey pine (<i>Pinus jeffreyi</i>).....	1.25 to 3.00
Lodgepole pine (<i>Pinus contorta</i>).....	3.55 to 7.00
Sitka spruce (<i>Picea sitchensis</i>).....	3.00 to 3.50
Western red cedar (<i>Thuja plicata</i>).....	3.50 to 4.00
Western white pine (<i>Pinus monticola</i>).....	3.00 to 5.00
White pine (<i>Pinus strobus</i>).....	1.10 to 2.25
Red pine (<i>Pinus resinosa</i>).....	6.00 to 8.00
Mexican white pine (<i>Pinus strobiformis</i>).....	
Arizona cypress (<i>Cypressus arizonica</i>).....	2.50 to 4.50
Bigtree (<i>Sequoia washingtoniana</i>).....	6.00 to 6.50
Noble fir (<i>Abies nobilis</i>).....	3.00 to 3.50
Grand fir (<i>Abies grandis</i>).....	1.50 to 4.00
Amabilis fir (<i>Abies amabilis</i>).....	3.50 to 4.00
California red fir (<i>Abies magnifica</i>).....	2.00 to 4.50
Scotch pine (<i>Pinus sylvestris</i>).....	1.50 to 2.50
Austrian pine (<i>Pinus austriaca</i>).....	.50 to 1.00
Norway spruce (<i>Picea excelsa</i>).....	.30 to .50
Maritime pine (<i>Pinus maritima</i>).....	.07 to .25

EXTRACTING THE SEED.

It is exceedingly important that the cones be dried and the seed extracted promptly after collection. An even better plan is to do this while the collection of the cones is in progress. Promptness is necessary because good drying weather does not continue in most parts of the West very long after the cones are ripe, and there is also need for having the fresh seed available for fall sowing. The plan usually followed in extracting yellow pine, Douglas fir, and spruce seed is to spread the cones thinly on canvas sheets to dry in the sun (Pl. III, fig. 1). This is usually much cheaper than transporting the cones to the drying house and opening them by artificial heat. The rate of drying in the sun depends upon the weather and the species. If the drying is likely to continue until the ground becomes cold and wet, it is well to keep the canvas off the ground by means of brush, or a slightly raised platform of some kind. At night and during damp weather the canvas sheet should be drawn up by the corners and either tied in bundles or one side thrown over the cones. In this way the cones retain to some extent the heat absorbed during the hours of sunlight, while the first plan serves the added purpose of protection against nocturnal rodents.

Cones of lodgepole pine are very difficult to open, and it is often necessary to resort to artificial heat. Even with this species, however, it is best to utilize the sun's heat in opening the cones, since collecting can be done in the summer, owing to the fact that lodgepole cones are persistent and remain on the trees for years. If the weather has been unfavorable for sun drying, or if collection has been unduly delayed, artificial drying may become necessary even for species usually dried in the open. It can not be too strongly

emphasized, however, that the sun and wind excel any drying house ever constructed. Where artificial drying is necessary the drying house should be roomy and fitted with tiers of trays arranged around the walls from 8 to 10 inches apart (Pl. III, fig. 2). The trays should be constructed with screen bottoms, with a mesh of suitable size to permit the seed to drop through upon the canvas sheet. After the trays are filled with cones the room is heated to and kept at a temperature of from 120° to 140° F. until the cones have opened. Thorough ventilation is necessary in order to carry off the moist air. Stirring the cones with an iron rake results in more even drying. As soon as the cones have opened they should be removed and threshed out and a fresh supply put into the trays. A temperature of 140° F. or more, if continued for any length of time, reduces the vitality of the seed. Twelve square feet of tray space will accommodate a bushel of cones. Soaking the cones of lodgepole pine for a short time before heating them in the drying house aids in the extraction of seed.

Figure 3 shows the plan of the cone-drying house on the Snoqualmie National Forest, Washington. This is roughly similar to the prune-drying houses of the Pacific coast, and is designed especially for Douglas fir cones. It has proved very satisfactory, though some slight improvements have been suggested since it has been in operation. One is to insert two or three stove-pipe radiators in the horizontal part of the pipe, in order to utilize the heat more fully. If the width of the floor upon which the trays are handled were increased about 1 foot it would probably add to the convenience in operation. It might be well, also, to make the ventilator, or oblong section, as long as the width of the drying compartment.

A number of sacks of cones are kept on a rough platform of boards, spaced a few inches apart, near the ceiling of the drying compartment. Cones stored here are dried to a considerable extent before they are placed on the trays. Cones in the lower trays nearest the stove pipe dry most rapidly, and when these are removed the upper trays are dropped down and the empty trays inserted above and filled from the sacks of cones stored overhead. In this way the freshly heated air from the pipe always strikes the driest cones before it has become partly moisture laden, thus insuring that cones which have become partly dried will not have an opportunity to absorb moisture again.

All the trays of the drying compartment are shaken at intervals of two or three hours, beginning with the top trays and shaking toward the bottom. Probably 75 per cent of the seed is removed from the cones in this way before they are taken from the trays. The floor of the drying compartment is tight and smooth, and all of the seeds are swept together with a floor brush immediately after the trays are

shaken, since they should not be subjected to high temperature after being released from the cones. The seed thus obtained is very clean and has few impurities, except the wings, and some sand and leaves. The capacity of the drying house on the Snoqualmie Forest is 50 bushels of cones or 62½ pounds of clean seed per day.

Several other cone-drying houses have been constructed on the National Forests, of which one of the largest is located at Custer, S. Dak., where during the four weeks from November 26 to December 24, 1910, a total of 3,894 pounds of clean seed were produced. To

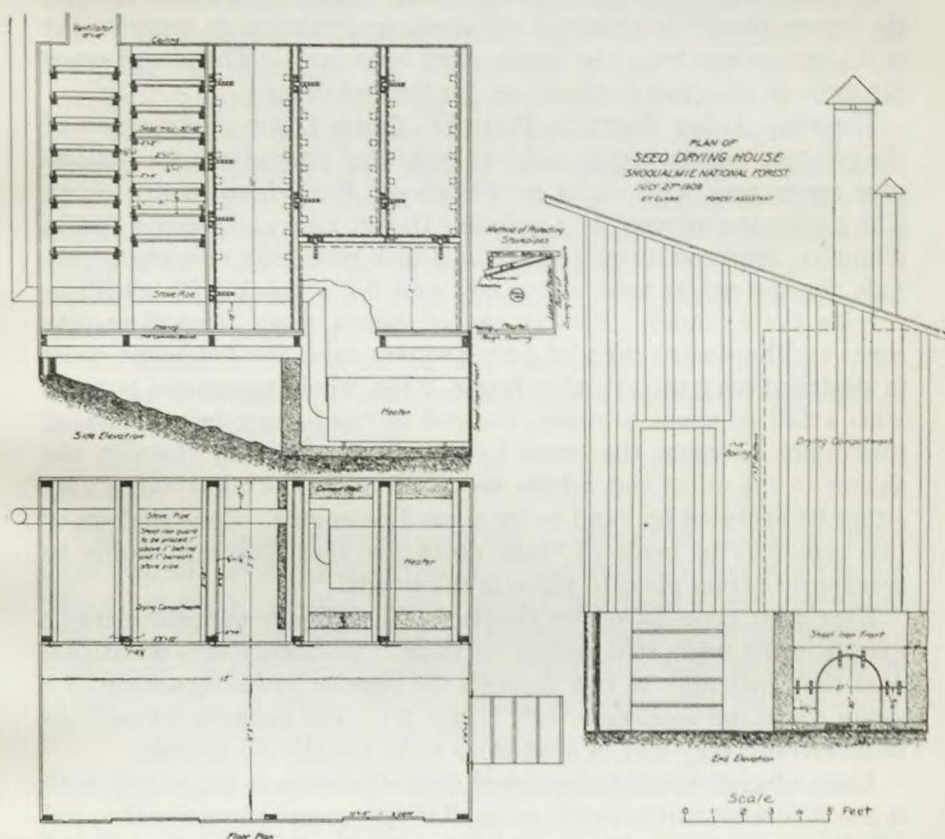


FIG. 3.—Plan of seed-drying house.

do this meant to handle 1,000 bushels per week, including drying and opening, shaking out the seed, removing the wings, treating the seed and putting it through a fanning mill, and weighing and sacking it for shipment.

Some species, such as yellow pine, in most cases need only a thorough raking of the dried and opened cones to dislodge the seed, while other species need severe and continued jarring. A variety of cone shakers have been devised by members of the Forest Service.

One in common use is made from a large dry-goods box, about 4 by 3 by 3 feet, provided at one end with a door made of slats so spaced as to permit only the closed cones to fall through (Pl. IV, fig. 2). This door should be fitted also with a removable wire screen of such sized mesh as to permit only the seed to escape. The box should be built on a pole as an axis and swung between two trees, or else mounted on a windlass. By a crank attached to one end of the axis the apparatus may be revolved and the seed loosened. Slats nailed lengthwise inside the box, or loose blocks of wood placed in the box with the cones, increase the jarring effect. After the seed has escaped the screen should be removed and shaking continued to separate the still closed cones from the larger sized open ones. The closed cones can even be returned to the house for further drying.

The cone shaker shown in Plate IV, figure 1, is a modification of the common potato sorter, and has been used extensively for yellow-pine cones, and, with slight modifications, for lodgepole-pine cones. The shaker is composed of a cylinder 16 feet long and about 4 feet in diameter, constructed on a shaft of 2-inch pipe long enough to provide for the supports at either end and for a crank with which to revolve the cylinder. Poultry net of $\frac{3}{4}$ -inch mesh for yellow-pine cones and hardware cloth of $\frac{1}{2}$ -inch square mesh for lodgepole cones is stretched over the cylinder frame. The whole apparatus is made with a fall of about 6 inches, the end of the hopper being elevated that much to cause the cones to travel automatically through the shaker to the other end, where they fall out. The contrivance may either be operated by hand or by a gasoline engine. Cone shakers of this type may be made to "take down," so that they can readily be transported from place to place in the woods.

Even after cones have been shaken in the ordinary way considerable quantities of seeds still adhere to them. To obtain this additional seed the cones may be run through the regular grain separator of a steam thrashing machine. (Pl. V, fig. 2.) The quantity of seed obtained in this way will in most cases fully justify the expense.

Even after the seed is separated from the cones it has mixed with it much foreign matter, such as small twigs, pieces of cone scales, and membranous wings. Much of this foreign material can be screened out to some extent, but to loosen the wings from the seed requires further treatment. Sometimes the seeds may be forced through a wire screen, which will scrape off the wings. A good plan is to sack the seed loosely and then knead it, after which it should be run through a fanning mill fitted with screens of the proper mesh. (Pl. V, fig. 1.) In small operations the seed may be cleaned by pouring it from one receptacle to another in a current of air.

TESTING THE SEED.

SEED-TESTING LABORATORY.

The Forest Service has in Washington a seed-testing laboratory, in which germination and purity tests are made and the number of seed per pound determined of all species collected on the National Forests. As each lot of seed is received it is passed through a seed-sampling machine, which divides it into two approximately equal quantities. This process is continued until one of the portions consists of a few more than 1,000 seeds, with the usual amount of rubbish. This portion is weighed, then cleaned of all rubbish, and reweighed. In this way the percentage of purity of the seed by weight is determined. From the same portion 1,000 seeds are counted out, weighed, and the number of seed per pound determined by proportion. Germination per cent is determined in two ways—first, by a cutting test on 200 seeds, and, second, by planting 200 seeds in a sand-filled flat and subjecting them to a hothouse temperature of about 60° F. The cutting test is, of course, only approximate, but it serves as a good basis for comparison with the actual germination secured by the planting of the seed.

In addition to these tests, the seed laboratory is conducting experiments to determine the relative merits of a number of methods of storing coniferous-tree seeds.

YIELD FROM CONES.

The yield of seeds depends upon the quality of the cones, the thoroughness of drying and extracting, and the manner of cleaning. There is a great variation in the yield of seed from a bushel of cones. The cones of any species fill better during a "seed year" than during "off years," so that in the former there is greater bulk, and especially greater weight of seed. Table 3 shows by species the average quantity of seed per bushel of cones or fruits.

TABLE 3.—Quantity of seed per bushel of cones or fruits of different species.

Species.	Number of pounds.	Species.	Number of pounds.
Douglas fir.....	1.25	Western red cedar.....	0.75
Western yellow pine.....	1.50	Black walnut (husked).....	40.00
Engelmann spruce.....	.80	Butternut (husked).....	40.00
Lodgepole pine.....	.25	Shagbark hickory.....	30.00
Sugar pine.....	1.60	Bitternut hickory.....	40.00
Western larch.....	.50	Pignut hickory.....	40.00
Sitka spruce.....	1.25	Red oak acorns (clean).....	50.00
Western white pine.....	1.00	White-oak acorns (clean).....	70.00
Red pine.....	1.00	Chestnut (clean).....	50.00
White pine.....	1.10		

NUMBER OF SEEDS PER POUND.

In Table 4 is given by species the approximate number of seeds per pound.

TABLE 4.—Number of seeds per pound.

Species.	Number of seeds.	Species.	Number of seeds.
Douglas fir.....	43,000	Red pine.....	55,000
Western yellow pine:		Mexican white pine.....	2,700
Pacific coast.....	9,100	Arizona cypress.....	100,000
New Mexico.....	16,000	Bigtree.....	75,000
Black Hills.....	13,500	Noble fir.....	¹ 15,400
Engelmann spruce.....	175,000	Grand fir.....	¹ 20,000
Sugar pine.....	2,400	Amabilis fir.....	¹ 13,700
Jeffrey pine.....	3,100	California red fir.....	¹ 67,000
Lodgepole pine.....	120,000	Scotch pine.....	69,000
Sitka spruce.....	400,000	Austrian pine.....	24,000
Western red cedar.....	400,000	Norway pine.....	54,000
Western white pine.....	28,000	Maritime pine.....	9,450
White pine (New York).....	26,000		

¹ Not Forest Service tests.

PERCENTAGE OF GERMINATION.

In Tables 5 and 6 is given the average percentage of germination for seeds of different species, and the real value of the seed based upon relative percentages of germination and of clean seed.

TABLE 5.—Percentage of germination of seeds of different species.

Species.	Germination.	Species.	Germination.
	<i>Per cent.</i>		<i>Per cent.</i>
Douglas fir (<i>Pseudotsuga taxifolia</i>).....	55	Mexican white pine (<i>Pinus strobiformis</i>).....	47
Western yellow pine (<i>Pinus ponderosa</i>).....	75	Arizona cypress (<i>Cupressus arizonica</i>).....	22
Engelmann spruce (<i>Picea engelmanni</i>).....	60	Bigtree (<i>Sequoia washingtonia</i>).....	15
Sugar pine (<i>Pinus lambertiana</i>).....	51	Noble fir (<i>Abies nobilis</i>).....	¹ 23
Jeffrey pine (<i>Pinus jeffreyi</i>).....	86	Grand fir (<i>Abies grandis</i>).....	¹ 34
Lodgepole pine (<i>Pinus murrayana</i>).....	83	Amabilis fir (<i>Abies amabilis</i>).....	¹ 42
Sitka spruce (<i>Picea sitchensis</i>).....	51	California red fir (<i>Abies magnifica</i>).....	¹ 65
Western red cedar (<i>Thuja plicata</i>).....	67	Norway spruce (<i>Picea excelsa</i>).....	48
Western white pine (<i>Pinus monticola</i>).....	57	Scotch pine (<i>Pinus sylvestris</i>).....	44
White pine (<i>Pinus strobus</i>).....	55	Austrian pine (<i>Pinus austriaca</i>).....	67
Red pine (<i>Pinus resinosa</i>).....	89		

¹ Tests not made by the Forest Service.

TABLE 6.—Practical germination per cent and real value of seed.

Species.	Practical germination.		Purity.	Real value ² (per cent).
	Days. ¹	Per cent. ¹	Percentage of clean seed by weight.	
Douglas fir.....	40	55	89	49
Western yellow pine.....	² 21	75	95	71.3
Engelmann spruce.....	14	60	81	48.6
Lodgepole pine.....	45	65	83	54
White pine.....	76	55	93	51.2
Western white pine.....	79+	57	86	49

¹ These figures represent the number of days when germination was practically complete and the percentage of germination within that time, rather than the absolute final germination record.

² Per cent germination $\times$ per cent clean seed.

100

³ Western yellow pine seed germinates more slowly on proceeding from the Rocky Mountains to the Pacific coast. Averages from both regions show that Rocky Mountain seed germinates in about one-third of the time required for seed from the Pacific coast.

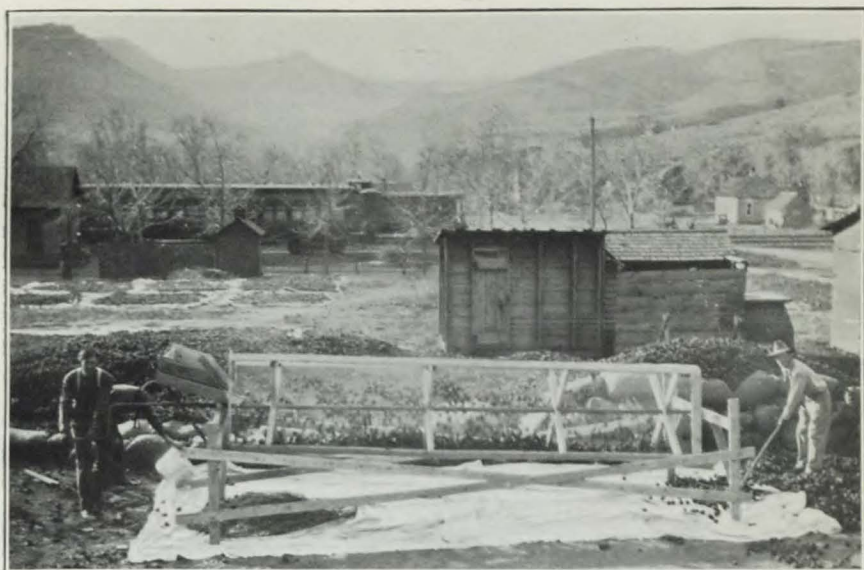


FIG. 1.—CONE SHAKER, COLORADO NATIONAL FOREST.



FIG. 2.—SHAKING CONES A SECOND TIME AND BURNING THEM.

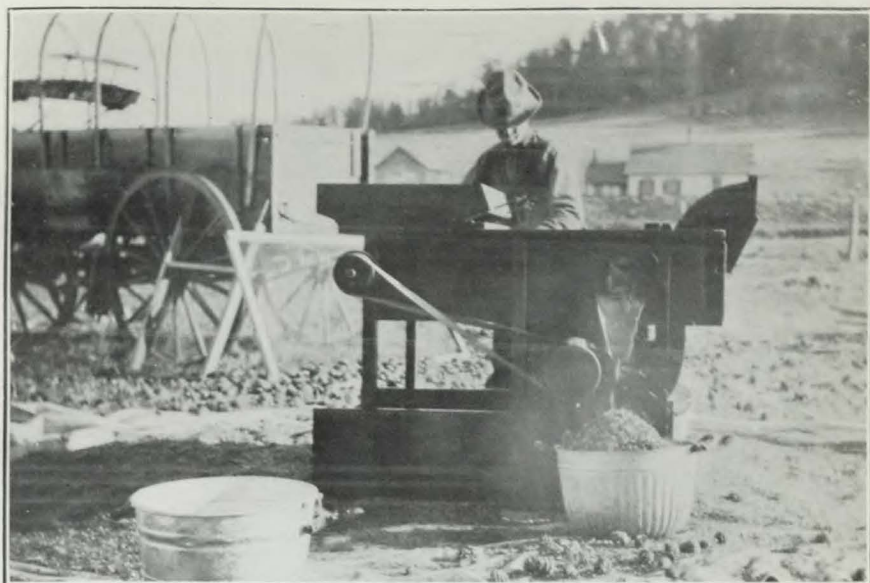


FIG. 1.—SEED FANNING MILL, BLACK HILLS NATIONAL FOREST.



FIG. 2.—CONES OF WESTERN YELLOW PINE BEING RUN THROUGH A STEAM GRAIN SEPARATOR.

METHODS OF STORAGE.

The necessity of storing seed, which sometimes arises, and the desirability of doing so in years of abundant crops, led the Forest Service to undertake experiments to ascertain the best method of storing seed of some of the most important of the coniferous trees. The species chosen for the test were *Picea engelmanni*, *Pinus contorta*, *Pinus monticola*, *Pinus ponderosa*, *Pinus strobus*, and *Pseudotsuga taxifolia*. The seed of these species were obtained in the following amounts from the sources indicated:

Species.	Quantity of seed.	Source of seed.
	<i>Pounds.</i>	
<i>Picea engelmanni</i> (Engelmann spruce).....	10	San Isabel National Forest, Colo.
<i>Pinus contorta</i> (scrub pine).....	12	Deerlodge National Forest, Mont.
<i>Pinus monticola</i> (western white pine).....	55	Coeur d'Alene National Forest, Idaho
<i>Pinus ponderosa</i> (western yellow pine).....	70	Boise National Forest, Idaho.
<i>Pinus strobus</i> (white pine).....	30	New York State forester.
<i>Pseudotsuga taxifolia</i> (Douglas fir).....	25	San Isabel National Forest, Colo.

The seed were spread out in a thin layer and fanned with an electric fan for two days in order to dry thoroughly the outside without affecting the interior. They were then divided into portions of about 600 to 800 each, and the total number of portions equally distributed among the following containers:

1. Ordinary manila paper bags.
2. Similar bags soaked in paraffin.
3. Cloth bags.
4. Cloth bags soaked in boiled linseed oil and dried.
5. Air-tight glass bottles sealed with paraffin.

To determine the effect of temperature and geographical location upon the seed, 13 points of storage, widely scattered over the United States, were selected, at which the seed was to be kept under different temperatures. The points of storage were:

Ann Arbor, Mich.	New Haven, Conn.
Dundee, Ill.	Pikes Peak, Colo.
Fort Bayard, N. Mex.	Pocatello, Idaho.
Halsey, Nebr.	State College, Pa.
Ithaca, N. Y.	Warsaw, Ky.
Lake Clear Junction, N. Y.	Waukegan, Ill.
Lawrence, Kans.	

In general, the different conditions of temperature under which the seeds were placed were:

- (1) Ordinary indoor temperature, such as office shelf, always above freezing.
- (2) Fluctuating temperature, as in barn or other outbuilding, where thermometer follows actual variations.
- (3) Uniform low temperature, as in a basement or cellar.

Since the experiments were planned to cover a period of five years, 12 sets of samples were sent to the storage points, of which 4 samples would be placed under each condition of temperature indicated. At the end of one, two, and five years one container of seed stored under each condition of temperature, or three containers in all, were to be shipped to Washington in order that germination tests might be made. One set of containers was sent in during the year of 1909-10, and the tests were made. The results obtained are, in all probability, fairly conclusive for seed stored for one year in the manner indicated in Table 7.

TABLE 7.—Germination per cent of seed stored under different temperatures.

Temperature and container.	<i>Picea engelmanni</i> .	<i>Pinus contorta</i> .	<i>Pinus monticola</i> .	<i>Pinus ponderosa</i> .	<i>Pinus strobus</i> .	<i>Pseudotsuga taxifolia</i> .	Average.	Average of all containers except oiled-cloth bag.
Fluctuating temperature:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Paper bag.....	47	66	36	75	41	23	48	55.5
Paper bag paraffined.....	40	74	37	76	44	26	49.5	
Cloth bag.....	38	54	30	75	31	14	40.33	
Cloth bag oiled.....	27	18	19	54	25	4	24.5	
Bottle.....	67	75	41	78	56	44	60.16	
Indoor temperature:								
Paper bag.....	52	69	36	75	46	29	51.16	57.7
Paper bag paraffined.....	55	77	39	77	50	34	55.33	
Cloth bag.....	51	42	32	77	35	25	43.66	
Cloth bag oiled.....	34	18	22	56	23	11	28.16	
Bottle.....	68	72	40	76	59	49	60.66	
Low temperature:								
Paper bag.....	30	64	33	72	32	14	40.84	46
Paper bag paraffined.....	41	71	35	72	38	20	46.16	
Cloth bag.....	24	49	27	74	27	8	34.84	
Cloth bag oiled.....	16	13	19	51	16	6	20.16	
Bottle.....	68	73	44	78	59	50	62.33	

A glance at the table shows that for all species the average germination is greater for seed stored in bottles than for that stored in any other container. If each species is considered separately it will be seen that with *Pseudotsuga taxifolia* germination of seed stored in the bottle exceeded that stored in any other container by from 15 to 30 per cent; with *Pinus strobus*, by from 9 to 21 per cent; and with *Picea engelmanni*, by from 13 to 27 per cent. In the case of the three other species the difference is in no way marked. The germination of *Pinus ponderosa* seed stored in bottles averages only 3 per cent more than that stored in the paraffined envelopes; and that of *Pinus monticola* only 5 per cent more; while the seed of *Pinus contorta* averages 1 per cent less than that stored in the paraffined envelopes. The uniformly high rate of germination shown by all seeds stored in bottles in the three temperatures, however, makes this method of storage seem in general the most desirable one.

The undesirability of storing seed in oiled cloth bags is very plainly brought out by the table. The low percentage of germination of seed so stored is probably due to the absorption of oil by the seed coats.

In attempting to determine the effect upon germination of the different temperatures under which the seed was stored, the germination percentage of those stored in the oiled bags was not considered, since its low figure was manifestly due to the container and not to the temperature. With the figures for the oiled bags eliminated, the following were the average percentages of germination under the different temperatures: Fluctuating, 55.5; indoor, 52.7; low, 46.

Seed stored in bottles showed, under the different temperatures, the following average percentages of germination: Fluctuating, 60.2; indoor, 60.6; low, 62.3.

It will be seen that the greatest difference in the percentage of germination under the three temperatures is only 2.1 per cent, and this might easily be due to a slight variation in the quality of the seed. It would seem, therefore, that differences in temperature have little or no effect upon seed stored in sealed glass bottles for one year. Another experiment discussed later tends to prove that the best temperature for storing seed is one ranging a little above 0° F. The object of storing seed in so many different places was to determine whether geographical situation has any effect upon germination. Table 8 seems to indicate that some locations should be given preference.

TABLE 8.—*Germination per cent of seed stored at different places.*

Location.	<i>Picea engelmanni.</i>	<i>Pinus contorta.</i>	<i>Pinus monticola.</i>	<i>Pinus ponderosa.</i>	<i>Pinus strobus.</i>	<i>Pseudotsuga taxifolia.</i>	Average of all species.
	<i>Per cent.</i> ¹	<i>Per cent.</i> ¹	<i>Per cent.</i> ¹	<i>Per cent.</i> ¹	<i>Per cent.</i> ¹	<i>Per cent.</i> ¹	<i>Per cent.</i>
Ann Arbor.....	61.9	67.0	36.9	76.6	39.0	23.7	50.9
Dundee.....	32.1	66.9	37.6	75.4	35.6	16.3	44.0
Fort Bayard.....	65.5	79.8	42.2	79.6	52.0	37.0	59.4
Halsey.....	52.0	60.0	34.8	74.1	42.7	30.0	48.9
Ithaca.....	47.8	66.1	35.2	70.6	44.0	34.8	49.8
Lake Clear Junction.....	57.4	63.4	32.0	77.2	55.0	41.4	54.4
Lawrence.....	27.4	69.1	28.8	72.6	25.8	17.0	40.1
New Haven.....	47.0	67.1	40.7	74.4	40.8	22.7	48.8
Pikes Peak.....	63.9	73.6	37.0	75.7	51.3	33.2	55.8
Pocatello.....	51.5	65.6	38.3	76.8	56.0	34.1	53.7
State College.....	47.8	57.6	34.9	71.9	43.3	27.8	47.2
Warsaw.....	36.8	58.0	33.8	76.1	31.6	17.2	42.3
Waukegan.....	46.1	58.5	33.4	76.1	43.9	25.5	47.3

¹ Average of all containers, except oiled bag, at all three temperatures.

The relatively high germination of seed stored at high altitudes, such as at Fort Bayard, Pikes Peak, and Pocatello, all in the Far West, is in striking contrast to that of seed stored at low altitudes in the Middle West, at Lawrence, Kans.; Warsaw, Ky.; and Dundee, Ill. The seed stored at Lake Clear Junction, N. Y., showed a relatively high percentage of germination, while that stored at the remaining points germinated moderately well. If conclusions can be drawn

from a storage period of one year only, it would seem that preference should be given to storage points in the dry eastern Rocky Mountain region, and that the Middle West should be avoided.

One set of experiments, in which the seed was stored in Washington only, was begun in 1906. With a single exception of one sealed jar, all the seed was stored in cloth bags, since the object of the experiment was primarily to determine the effect of temperature upon the stored seed. *Pinus torreyana*, *Pinus divaricata*, *Abies concolor*, and *Pseudotsuga taxifolia* were the species used. The seed were stored under the following conditions:

(1) Office shelf, seed laboratory, temperature never below 32° F.
 (2) Unheated room in seed store, in which temperature follows natural changes.

(3) Seed laboratory, in sealed jars, temperature never below 32° F.

(4) Chill room, storage warehouse, temperature 6° to 10° F.

Tests made on the seed during the winter of 1909-10 gave the results shown in Table 9.

TABLE 9.—Germination per cent of seed stored under different temperatures, Washington, D. C.

Species.	Office shelf, seed laboratory.	Unheated room, Bologniano's, fluctuating temperature.	Sealed jar, seed laboratory.	Chill room, temperature 34° to 36° F.	Freezing room, temperature 6° to 10° F.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
<i>Pinus ponderosa</i>	51.0	43.5	48.0	48.5	67.5
<i>Pinus attenuata</i>	52.5	54.5	62.0		53.5
<i>Pinus divaricata</i>	33.0	23.0	74.0		90.0
<i>Abies concolor</i>					28.0
<i>Pseudotsuga taxifolia</i>				5.5	21.0

Although these tests are rather meager ones upon which to base conclusions, the results at least indicate that more attention might profitably be given to storing seed at low temperature.

PART II.—DIRECT SEEDING.

DIRECT SEEDING VERSUS PLANTING.

Of the two methods of artificial reforestation—direct seeding and planting—the first offers for certain species on many of the National Forests by far the greater promise of success. By it the slow, complicated, and expensive process of raising plants in a nursery is eliminated. The seeding itself is a much more simple operation than field planting and can be done with less experienced labor. The seeding is limited mainly by the quantity and kind of seed available and its cost. In general, hardy trees, the seed of which is easily and cheaply obtained, can be reproduced satisfactorily by direct seeding, while species like red pine, which bear small crops of seed that are difficult to collect even under the most favorable conditions, can be reproduced more cheaply by planting.

In Russia reforestation by direct seeding has been practiced for years. Over 65,000 acres a year are reforested artificially by this method in the northern and northeastern Provinces. In India and in southern France, also, direct seeding has been carried on extensively. The maritime pine forests of southern France were established almost entirely in this way.

PAST WORK ON THE NATIONAL FORESTS.

Direct seeding was first tried on the National Forests in 1901, when seed was broadcasted or dropped into holes made with a stick on the San Bernardino Forest Reserve, in California. The site selected was in the dry foothills, and the experiment was, as might have been expected, a total failure. In 1902 red cedar, western yellow pine, jack pine, and blue spruce were sown on the snow in the Nebraska National Forest, and in the spring of 1903 an area of 25 acres was seeded to yellow pine. Corn planters were used, and the seed was placed part in furrows and part in sod. Both of these experiments, however, resulted in failure; few seedlings, except those of red cedar, survived. In 1902 some direct seeding was done on the San Gabriel National Forest, in California. The seed was of sumac, *Rhus laurina*, and about 1,000 pounds were used. The seeding was done on a rocky cliff, several hundred feet high, facing the east, below the astronomical observatory on Mount Wilson, and was very successful.

The first successful work in direct seeding on a large scale was done in 1905, at the request of the Secretary of Agriculture, on the Black Hills National Forest. Here approximately 28 acres were broadcasted and 12 acres seeded with corn planters to western yellow pine of the crop of 1903, from the Pecos National Forest, New Mexico. The results were excellent, the best being upon areas where corn planters had been used. The sowing was continued in the Black Hills in 1906, 1907, and 1908, with Black Hills seed of the crop of 1905. The results in 1906 were poor, in 1907 good, and in 1908 rather poor again. Additional sowing in 1908 with some old western yellow-pine seed collected in Nebraska gave very poor results, as did other experiments that year with Douglas fir. In 1909 approximately 650 acres in the Black Hills were broadcasted with local yellow-pine seed of the crop of 1908. The results were fair, but by no means entirely satisfactory. In view of what has been learned since, it seems probable that rodents were largely responsible for these poor results, since the weather conditions that year appeared perfect. It is probable that the success of the 1905 planting was due to the fact that it was done on an extensive burn, where there was no cover for rodents. Possibly the fact that plenty of seed was produced in the forest that year, furnishing the rodents an ample supply of food, had a direct bearing upon the success of the sowing. Direct seeding has since been carried on in hundreds of different places throughout the National Forests of the Rocky Mountain and Pacific Coast States. In the calendar year 1910 approximately 14,000 acres were sown by this method.

SELECTION OF THE SITE.

In the work of direct seeding too great emphasis can not be laid on the importance of selecting the right site for sowing. Large burns without grass cover which are not restocking, or are coming up to aspen, offer good sites for reforestation. Aspen lands and natural brush lands, not chaparral, are also excellent. Parks, grassy woodlands, alpine meadows, and sagebrush lands are less favorable. Some species demand one situation, some another. Even the chemical composition of the soil should be considered. Some species, like Douglas fir in the Rocky Mountains, prefer limestone formations, while others, like yellow pine and lodgepole pine, prefer soils containing little or no lime. In general, the seed of any species should be sown in a place and under conditions as like as possible to the site and conditions of its natural habitat.

TIME OF YEAR FOR SEEDING.

The time of year when seeding should be done varies with the climate, and to a less degree with the species. The important thing is to vary the time of sowing with climatic conditions, so that the

seedlings will get the greatest possible supply of moisture. Fall sowing has been successful more often than either spring or summer sowing, and appears to be advisable in Colorado, Utah, southern Idaho, California, western Montana, Washington, and Oregon. Except in the high mountains, the climate of Utah and southern Idaho, where considerable sowing has been done, is semiarid. The major part of the precipitation comes in the winter in the form of snow, while after its disappearance in the spring a hot, dry period of several months usually follows. In this region seed sown in the spring has often failed to germinate, or if it has germinated, the seedlings have soon dried up. Except in a few localities, therefore, and with species the seeds of which germinate quickly, spring sowing in Utah and southern Idaho offers little prospect of success. With fall sowing the chances are better, since the seed germinate early in the spring, enabling the plants to become more firmly established before drought begins. Early spring sowing has given good results in South Dakota, Wyoming, eastern Montana, and the Lake States. Summer sowing, just before the short rainy season, may be successful in Arizona and New Mexico, though spring sowing has also given good results. In Florida sowing should probably be done in the late winter.

Sowing on the snow in late winter and early spring gives satisfactory results under certain conditions. The seed is washed down into the mineral soil by the melting snow and is ready for germination when the snow disappears. This enables the young seedlings to take advantage of the spring rains, except in regions where spring is a season of severe drought, in which case spring germination may be a positive disadvantage. With seeds that need considerable soaking before germination will take place winter sowing is an advantage, while with seeds that are easily perishable it is a disadvantage. Seeds when first sown on snow are very conspicuous and are likely to be eaten by birds, though after a day or two of sunshine they disappear. Broadcasting is, of course, the only method of sowing practicable during winter.

Spring sowing has the advantage of not exposing the seed to unfavorable weather conditions or to destruction by birds and rodents longer than is necessary. Unlike winter sowing, it does not restrict the choice of methods, and the seed can be sown either broadcast or in seed spots, on either prepared or unprepared soil.

The seed of certain species like white oak, the cedars, and spruces is difficult to keep over winter, so that for them the time of sowing is in most cases restricted to the fall. Red oak acorns sown in the spring require from five to six weeks for germination. White oak and chestnut oak acorns sown in the fall often sprout before Christmas. White oak acorns are eaten greedily by squirrels, mice, turkeys, and hogs, and spring planting would be profitable if it were not so

difficult to start them. Where the danger of loss during the winter, however, is especially great, spring sowing may be tried. Red and black oak sprout only in the spring, but since they are bitter and in consequence are little molested by rodents, can be planted in safety in the fall.

In general, tree seed should be sown immediately preceding or at the beginning of the characteristic period of precipitation in the region. Exception to this rule may be necessary on account of local climatic conditions, peculiarities of certain tree species, or local abundance of rodents.

BROADCASTING.

Under favorable conditions tree seed may be scattered on unprepared ground with a fair prospect of success, though in most cases some preparation of the ground is necessary. In deciding upon the best method of preparing the ground for sowing, the surface, slope, and character of the ground cover, as well as the species to be sown, must be considered. Some of the methods used with good results are burning, harrowing with an ordinary spring-tooth or disk harrow, dragging tree tops or stumps over the ground, and plowing. An area thoroughly trampled by sheep, or which has been used as a sheep driveway, the soil of which is naturally loose, is usually in good condition for sowing. Certain tracts on the National Forests, each with a different kind of soil, are being purposely overgrazed in order to prepare the ground for the reception of seed.

Broadcast sowing may be expected to be successful where the soil is loose and moist at the surface, where some protection is afforded to seedlings against heat and drought, and where rodents can be controlled. Since rodents are much more numerous on the edge of green timber than in the open, sowing, to be most successful, should be a half a mile or more from the thickest growth. Burned areas covered with down timber, aspen, or brush of not too dense a character, but without much leaf litter, offer good sites for broadcast sowing without preparing the ground or covering the seed. As a matter of fact, harrowing or otherwise wounding the soil preparatory to broadcasting is almost impossible on mountain sides covered with a mass of down timber. On areas broadcasted seedlings are likely to come up in groups, due to erosion and to destruction by rodents. In sowing broadcast the seed should be weighed out with care, and one-half of the amount sown over the whole area. The sower should then travel back and forth at right angles to his previous course and sow the other half. In this way a more even distribution of the seed is assured. It is much more difficult to sow evenly 2 quarts of small tree seed than 2 bushels of corn. Large or medium-sized seed, such as that of yellow pine or Douglas fir, can be sown by hand, while



FIG. 1.—DIRECT SEEDING OF DOUGLAS FIR, SOLEDUCK BURN, OLYMPIC NATIONAL FOREST.



FIG. 2.—SEED-SPOT SOWING, WENATCHEE NATIONAL FOREST, WASH.

small seed, such as that of lodgepole pine, larch, and spruce, should be scattered with a mechanical seed sower. When very small seeds are used they can sometimes be scattered more uniformly by mixing them with fine, dry earth. Covering seed that has been broadcasted by harrowing or otherwise has not yet given good results, though further experiments along this line will be undertaken. Damage from rodents is usually less, or at least less noticeable, in the case of broadcast sowing than with other methods, since the seed is distributed over a wider area, there is more of it, and it is more difficult to find.

SOWING IN STRIPS AND BLOCKS.

Strip sowing and block sowing are modifications of the broadcast method. Sowing in strips has the advantage that it does not require the preparation of the entire area, thus reducing the cost. Narrow strips, 3 feet wide or less, are prepared in various ways, frequently by plowing. On hillsides the strips should run along contour lines, not up and down. Strips so run catch and retain the precipitation, and also prevent the soil and seed from being washed down by rain. In a flat country they should run east and west, and when a plow is used the furrows should be turned toward the south. In this way seedlings are given some protection from drought during the first year. Less seed per acre is required in strip sowing, but the seed is sown more thickly on the strip seeded than on the area broadcasted. Seed may be sown even without preparing the ground. It is a method particularly adapted to quick-growing species.

In sowing by both the broadcasting and strip methods machinery can sometimes be used to advantage. Where the slope is not too steep, and where down timber, brush, and rocks do not prevent, corn planters drawn by horses can be used. Hand planters of several kinds have been used extensively and have proven satisfactory. On an average one man can sow a little more than 2 acres a day with a hand corn planter. Before using hand planters the "shoe" should be modified so that it will not push the seed deeper than is desired. The edges of the shallow holes made by the corn planter crumble in and cover a part or all of the seed to about the right depth. The chief objection to all of the hand planters now on the market is that both hands are required to operate them. The Forest Service is now preparing plans for a machine which will be possible to operate with only one hand, and which in other respects is better adapted to the small, light seeds of coniferous trees.

The seed of broadleaf trees, nuts, acorns, etc., are easily dibbled in. A pointed staff is thrust sharply into the ground and pried about so as to slightly loosen the soil. It is then withdrawn so as

to leave an open hole, into which the acorn or nut is dropped. Merely stepping on the spot is sufficient to cover the seed. During rainy weather or after severe forest fires the ground is sometimes soft enough to permit of satisfactory sowing by dropping the nuts or acorns on the surface and crushing them in by stepping on them. More seed and closer spacing should be used when this is done.

SEED SPOTS.

The seed-spot method has some decided advantages over broadcasting or sowing in strips. Less seed per acre is required, the prepared spot gives the seed a better chance to germinate, and the seedlings have a better chance to grow, because the prepared spots are usually made in the most favorable places. Moreover, the result of the sowing can be more readily determined.

The spots are usually prepared with a mattock, a heavy hoe, or an iron rake (Pl. VI, fig. 2). The size of the spot and the depth to which the soil is loosened depend upon the character of the ground cover and the species to be sown. The spots are usually made square, with a side of from 12 to 20 inches. In locating them advantage is, of course, taken of any suitable shelter available. On level ground the turf is thrown upon the southern side of the spot to avoid the reflection from the sun's rays and the consequent baking of the young plants. On slopes the soil is thrown upon the lower edge of the spot in order to aid in holding moisture and to preclude the burying of the young seedlings by washing from above. The distance between the seed spots varies with the species and the character of the ground, in the case of slow-growing species usually about 2 feet apart, while with more rapid-growing trees the distance between them may be 8 or 9 feet. In some cases loosening the ground to a depth of more than 2 or 3 inches seems inadvisable, since the loosened soil dries out rapidly and the seedling is injured before its roots have had a chance to penetrate the unloosened moist soil beneath. The chief function of the spot is to make sure that the seed reaches the mineral soil, and partially to eliminate, for a time at least, competition with grass and other plants. Where the ground cover consists of strong-growing plants and plants which produce heavy shade during the growing season spots should be even more than a foot wide. Where a shade-enduring species is being sown on a moist situation the spots may even be less than a foot wide.

In seed-spot sowing three men constitute a good crew, two selecting and making the spots, and one sowing the seed. In practice it is found that the man dropping the seed can also cover it, whenever this is advisable, and yet keep up with the men preparing the spots. Coniferous seed, except that of the largest, like sugar pine, should in no case be covered to a depth of more than one-half inch.

Areas sown by the seed-spot method suffer more damage from birds than do those sown by other methods. A thicker sowing in seed spots is therefore necessary. Where, however, too many seed are used per spot, and these are unmolested, the resulting growth is much too thick, and the tree trunks do not develop normally. The interior trees are too slender, and the competition for light and moisture during the early stages of growth is too great. Moreover, the completion of a fully stocked stand is retarded, and soil protection is in consequence postponed for a long time.

The so-called hole or pit method of direct seeding is the same as the spot method. The prepared spot is smaller and somewhat deeper. It is used on very dry, barren, stony ground, in sunny, hot, or windy situations.

QUANTITY OF SEED PER ACRE.

In the forest during most years nature produces seed abundantly, depending upon quantity to offset possible adverse conditions. In artificial sowing it is not practicable to be so lavish, and conditions that will permit the germination of the seed and enable the tiny plants to grow must be insured. One of the chief problems is to get the seed into direct contact with the soil. An old grove of Douglas fir trees may shed 25 pounds of seed to the acre, or 1,250,000 individual seeds, yet because of needles and litter covering the ground probably less than one seed in ten thousand reaches the mineral soil, germinates, and grows. With Douglas fir direct light is, of course, an important factor also. By removing the heavy shade, by burning the litter and exposing the mineral soil, and by poisoning destructive rodents, conditions may be so improved that 3 pounds of seed to the acre, sown broadcast, or 1 pound sown in seed spots, will produce a full stand of young trees.

With a suitable area well prepared, the amount of seed of the more important species required per acre is about that shown in Table 10. The amounts are based on the average germination per cents given in Table 9. The Forest Service seed testing laboratory annually determines the germination per cents of the seed collected on different forests, and the amount sown per acre should be varied in accordance with these tests.

TABLE 10.—*Number of seed required per acre.*
BROADCAST SOWING OVER THE WHOLE AREA.

Species.	Pounds of seed per acre.	Species.	Pounds of seed per acre.
Douglas fir.....	4 - 5	Red pine.....	4
Western yellow pine.....	6 - 8	Mexican white pine.....	8-10
Engelmann spruce.....	2 - 4	Noble fir.....	8-10
Sugar pine.....	10 -20	Grand fir.....	8-10
Jeffrey pine.....	18 -24	Amabilis fir.....	8-10
Lodgepole pine.....	2 - 3	California red fir.....	8-10
Sitka spruce.....	2 - 3	Scotch pine.....	7- 8
Western red cedar.....	1½ - 2½	Austrian pine.....	8-10
Western white pine.....	8 -10	Norway spruce.....	5- 7
White pine.....	8 -10	Maritime pine.....	10-20

SEED-SPOT SOWING.

[Spots 6 by 6; approximately 12 good¹ seed per spot.]

Douglas fir.....	1	Mexican white pine.....	3
Western yellow pine.....	2½	Arizona cypress.....	3
Engelmann spruce.....	4	Bigtree.....	2
Sugar pine.....	6	Noble fir.....	3
Jeffrey pine.....	8	Grand fir.....	3
Lodgepole pine.....	1	Amabilis fir.....	3
Sitka spruce.....	1	California red fir.....	3
Western red cedar.....	1	Scotch pine.....	2½
Western white pine.....	2½	Austrian pine.....	3
White pine.....	2½	Norway spruce.....	2
Red pine.....	1½	Maritime pine.....	4

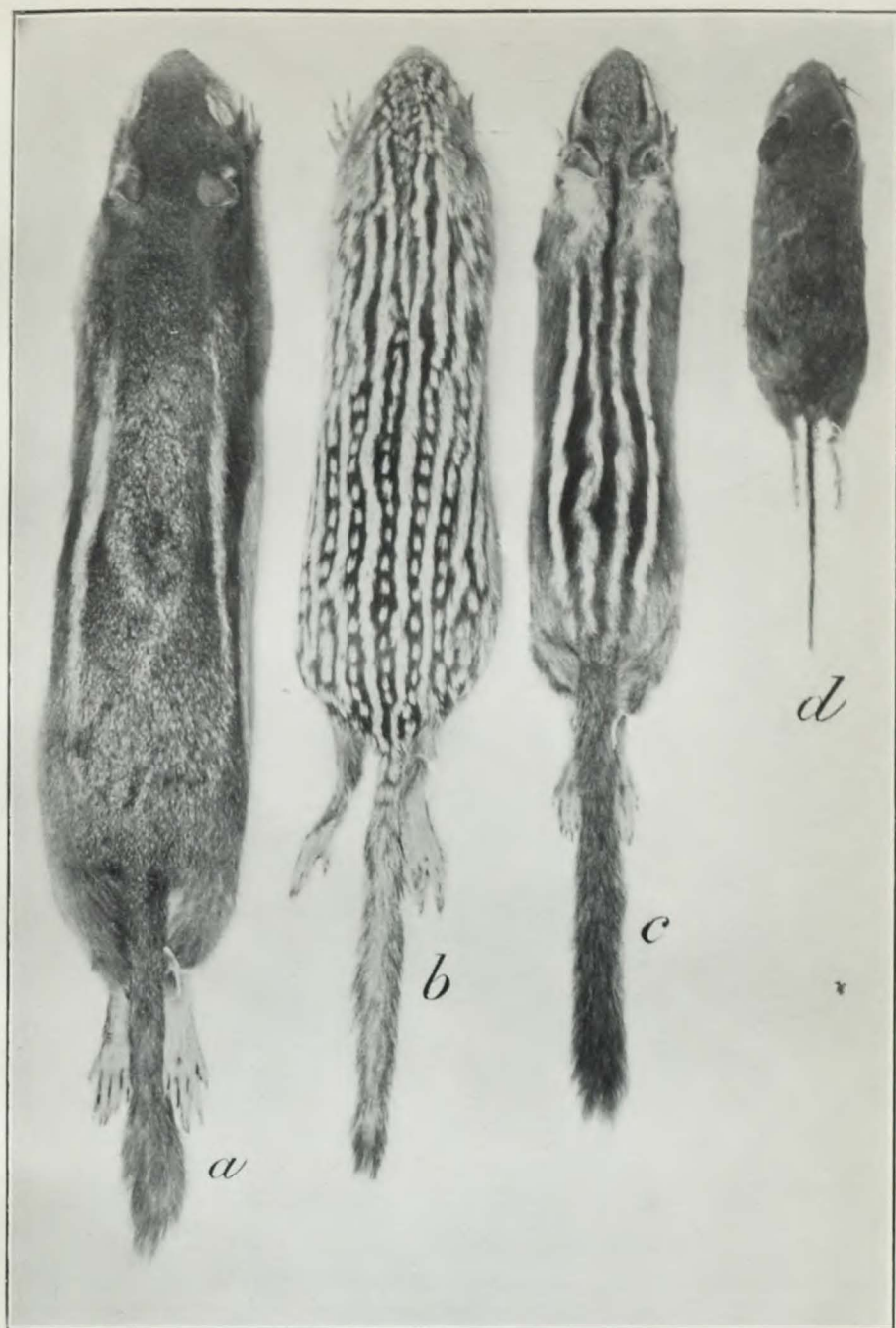
¹ For example, if the germination tests showed 50 per cent germination, 24 seed would have to be sown to have 12 good seed.

The germination period varies with weather conditions and with the quality and kind of seed. The approximate number of days of "growing" weather after sowing required by different species varies from 14 to 22 days. The temperatures at which tree seeds sprout in the shortest time lie between 66° and 68° F.

PROTECTION FROM RODENTS.¹

In some parts of the West farmers suffer heavy loss from rodents. Toll is taken of seed grain by mice, squirrels, and pocket gophers, and this in spite of the fact that the farmer sows as much as 100 pounds of wheat to the acre and by annual plowing and further cultivation renders conditions inimical to the domestic life of the rodents. When under such conditions these little animals cause serious injury to seed grain and to growing crops, it is but natural to expect much greater damage when tree seed is sown. A rodent population sufficient to eat or store 10 out of 100 pounds of wheat sown on an acre could make away with all of the necessarily few pounds of tree seed sown. The actual rodent population on wild land in or near the woods is probably greater, and is certainly more varied, than in cultivated fields. Tree seed is very attractive to rodents and is more

¹ This subject is treated in Circular 78 of the Biological Survey, "Seed Eating Mammals in Relation to Reforestation," from which the formulas given here are taken.



FOUR COMMON RODENTS DESTRUCTIVE TO TREE SEED.

(a) Say ground squirrel (*Callospermophilus lateralis*); (b) Pale-striped ground squirrel (*Citellus tridecemlineatus pallidus*); (c) Rocky Mountain chipmunk (*Eutamias quadrivittatus*); (d) White-footed mouse (*Peromyscus maniculatus rufinus*). (From Circular 78, Bureau of Biological Survey.)

palatable than grain. In many cases it is their natural food, and they are wonderfully diligent and expert in searching it out. Many experiments in the direct seeding of hardwoods and conifers have failed because nearly all of the seed was eaten by mice, chipmunks, and other animals. Where tree seed attractive to rodents is to be sown it is necessary, therefore, to consider the systematic poisoning of the area as an essential operation. In the experiment conducted at the Coconino Experiment Station seed spots were sown to yellow pine and then covered with small portable screens which effectively protected them from rodents and birds. The successful germination in these spots and the absolute failure in similar unprotected spots adjacent showed how important an adverse factor animals are in reforestation.

In the spring of 1910, in cooperation with the Biological Survey, intensive studies of the damage from rodents were conducted at a number of places where direct seeding was in progress, while on many other sowing areas observations were made by Forest officers. In nearly every case a different species of animal was found to be the chief cause of damage. There are, of course, a great many species of mice, chipmunks, and ground squirrels, and a number of different kinds of tree squirrels. Each species appears to have distinctive habits, while the food and activities of the same species differ greatly with the time of year. The kind of poison bait and the manner of applying it must, therefore, be adapted not only to the species of animal to be destroyed, but to the taste and activities at the time the poisoning is done.

In a certain locality on the Black Hills Forest, in the spring of 1910, where 600 acres were to be sown to Austrian pine, yellow pine, and Scotch pine, it was found that white-footed mice of the genus *Peromyscus* were gathering and eating from 20 to 25 per cent of the seed, while in another locality on the same Forest chipmunks (*Eutamias quadrivittatus*) proved to be the important factor in the seeding operations. With the assistance of experts from the Biological Survey these pests were greatly reduced in numbers and their depredations practically stopped by means of poisoning. Chipmunks of one species or another are abundant in most of the National Forests, ground squirrels are common and troublesome, and mice, especially of the genus *Peromyscus*, constitute a widespread pest. With the systematic use of poison, however, these pests can be so reduced as to be practically harmless. A good formula for poisoning chipmunks and ground squirrels is the following, which was recommended by the Biological Survey and has been used with good results:

Strychnia sulphate-----	1 ounce.
Saccharin-----	1 teaspoonful.
Gloss, or laundry starch-----	$\frac{1}{2}$ cupful.
Water-----	1 quart.
Barley-----	20 pounds.

The strychnia and saccharin are dissolved in the water by boiling, after which the starch, previously softened with cold water, is poured in and the boiling continued until the solution thickens. This solution is then mixed with the grain until the kernels are coated. The treated bait may be used at once, or it may be dried and kept for future use. In distributing the poisoned grain or other bait the places selected should be numerous, though the quantity left at each may be small, since only a few kernels are required to kill an animal. Poisoning works best when ordinary rodent food is scarce. The poison just given for chipmunks and ground squirrels is most effective in spring or early summer. Planting the poisoned seed itself is apt to be unsatisfactory, since the poison is all on the shell and is not eaten by the rodents, which merely extract the kernel and leave the shell. This method may, however, be effective in the fall when the rodents are storing seed and the poison is absorbed as the seed is carried in the cheek pouches of the animals.

Where mice as well as chipmunks are destructive, the following formula has proven effective:

Wheat.....	16 quarts.
Strychnin.....	1 ounce.
Saccharin.....	1 teaspoonful.
Melted tallow.....	1 pint.

Either the alkaloid or the sulphate of strychnin may be used, though the alkaloid on account of its less bitter taste seems preferable. The wheat should be warmed in a metal saucepan or small receptacle, and the saccharin and strychnin pulverized and sprinkled over it. The melted tallow should then be poured in and the mixture stirred until every wheat kernel is coated. Tallow is more satisfactory than starch as a coating in wet weather, and wheat is more effective than barley, especially for mice.

In distributing any kind of poisoned grain it is important to put it out of the reach of birds. Ordinarily this is not difficult. Cavities among small piles of stones or under roots or logs, or burrows of animals, will be entered by rodents and ignored by birds. Lacking these, cover made from pieces of bark, boards, or flat stones, with a low runway left beneath, will fill the purpose. Barley is usually attractive to rodents and is the grain least relished by birds.

In some of the National Forests rabbits have damaged plantations of young trees. Where damage of this kind is serious the rabbits should be poisoned in early spring by baiting with twigs cut from fruit trees or native brush. The twigs should be scattered a few hours before sundown along the rabbit trails, or in openings on the plantations. The bait should be prepared according to the formula given for chipmunks and ground squirrels, with the substitution for the barley of 15 pounds of twigs cut into 2 or 3 inch lengths.

In the poisoning work done on the National Forests in 1910, it was found that to cover an area thoroughly requires 1 bushel of poisoned wheat to every 40 acres, a pinch of the grain being dropped at intervals of 15 feet, in rows 40 feet apart.

Petroleum should not be used to protect seed from animals, since it destroys the vitality of the seed. Red lead has proven useful in protecting acorns and nuts from rodents. Its use delays germination only slightly, but the protection it gives is not thorough. Sometimes it appears even to attract birds and certain rodents. It is applied by placing the wet nuts or acorns in a bag containing red lead and shaking thoroughly. It should not be used if there is danger of domestic stock, such as hogs, getting at the plantation. Carbolic acid solutions injure seed, and are of doubtful value as protection from animals.

PROTECTION FROM STOCK AND FIRE.

The grazing of live stock is prohibited upon areas within the National Forests seeded to either coniferous or broadleaf species. The small areas where experiments are being conducted require fencing, and upon tracts where sowing is being done on a large scale notices are posted closing the area to grazing. This, with proper supervision, will prevent damage from herded stock. Where walnuts, hickory nuts, acorns, and even maritime pine seed are being sown, there is a fence to keep out hogs.

Since the lightest kind of grass or ground fire will destroy young seedlings, it is necessary to keep out fire absolutely. Every precaution justified by the importance of the experiment and the value of the plantation is taken to prevent fire. This, of course, applies to planted as well as to seeded areas.

COST OF SOWING.

There are many elements which have a material bearing upon the cost of sowing. The more important of these are the character of the land to be sown, the method of sowing, and the species of seed used. Seed of the same species may be sown by the same method on two sites of equal area, yet the cost of sowing one of them will be much less than that of sowing the other, because of the different character of the land. Again, where land of two sites and equal area is similar in character, and the same method of sowing is followed, the cost may vary, because on one site the species of seed sown cost more than that sown on the other. Other things being equal, the method of sowing is the element which most influences the cost. The following discussion of costs under various methods and on different kinds of sites is based on actual experiments conducted on the National Forests. In

general, the sites upon which the sowing was done may be divided into three classes.

Class I: Level or open country, with little or no ground cover to be removed, no down timber to obstruct the movements of the planters, and with soil light and easily worked.

Class II: New burns on fairly level or gently sloping ground, with no ground cover, but with large quantities of dead timber; the soil of clayey loam, but easily worked with a grub hoe.

Class III: Steep slopes with considerable ground cover, and with much down timber; the soil often containing much loose rock.

The species of seed sown and the cost per pound were as follows: Norway spruce, \$0.55 per pound; yellow pine, \$1 per pound; Douglas fir, \$1.50 per pound.

In all classifications a uniform cost of 46 per cent per acre is made for expenses, exclusive of the cost of preparing the ground or sowing the seed, and of the seed itself. These expenses consist chiefly of surveying and staking out the sites, transporting camp equipment and supplies, and the general expenses of Forest officers. This miscellaneous expense will, of course, vary, but the estimate of 46 cents per acre is an average of seven representative projects. In calculating the cost of labor the wage used was $32\frac{1}{2}$ cents per hour per man, exclusive of subsistence, and 75 cents per hour for a man and a team working on an eight-hour basis.

CLASS I SITE.

Method A. Seed spots 10 to 12 inches in diameter; the soil stirred only from 1 to 2 inches; the seed covered, and the soil lightly tamped.

By spacing 6 by 6 feet and sowing from 10 to 15 seeds per spot, it cost per acre for Norway spruce \$2.10, for yellow pine \$3.70, and for Douglas fir \$2.49. With the same spacing, but with from 20 to 30 seed per spot, it cost per acre for Norway spruce \$2.21, for yellow pine \$5.59, and for Douglas fir \$2.99. By spacing 5 by 5 feet, with from 10 to 15 seed per spot, it cost per acre for Norway spruce \$2.59, for yellow pine \$5.01, and for Douglas fir \$3.16. With a spacing of 5 by 5 feet, but with from 20 to 30 seed per spot, it cost per acre for Norway spruce \$2.77, for yellow pine \$7.61, and for Douglas fir \$3.91.

Method B. Large seed spots 2 feet in diameter; soil cultivated to a depth of 6 inches and seed covered.

By spacing 9 by 9 feet and sowing from 10 to 15 seed per spot, it cost per acre for Norway spruce \$1.57, for yellow pine \$2.26, and for Douglas fir \$1.71. With the same spacing, but with from 20 to 30 seed per spot, it cost per acre for Norway spruce \$1.64, for yellow pine \$3.02, and for Douglas fir \$1.92.

Method C: Double furrows plowed 8 feet apart and harrowed; 8 seed used per square foot of furrow, and furrows harrowed again.

By this method it cost per acre for Norway spruce \$3.75, for yellow pine \$13.03, and for Douglas fir \$5.79.

Method D: Harrowing in strips 8 feet apart twice before and once after sowing. Eight seed sown per square foot.

By this method it cost per acre for Norway spruce \$2.92, for yellow pine \$12.20, and for Douglas fir \$4.96.

Method E: Complete broadcasting without any preparation of the ground; area traversed once.

By sowing 100,000 seed to the acre, the cost (per acre) for Norway spruce was \$1.52, for yellow pine \$12.62, and for Douglas fir \$4.22. With 150,000 seed to the acre, the cost for Norway spruce was \$1.97, for yellow pine \$18.62, and for Douglas fir \$6.02. With 200,000 seed to the acre, the cost (per acre) for Norway spruce was \$2.42, for yellow pine \$24.62, and for Douglas fir \$7.82. With 250,000 seed per acre, the cost for Norway spruce was \$2.87, for yellow pine \$30.62, and for Douglas fir \$9.62. If the area had been traversed twice instead of once, the cost in each instance would have increased approximately 16 cents an acre.

CLASS II SITE.

Method A: Seed spots 12 inches in diameter, spaced 9 by 9 feet; the soil stirred to a depth of from 1 to 2 inches; seed covered.

With from 10 to 15 seed per spot, the cost per acre for Norway spruce was \$1.86, for yellow pine \$2.55, and Douglas fir \$2. With from 20 to 30 seed per spot, the cost per acre for Norway spruce was \$1.93, for yellow pine \$3.31, and for Douglas fir \$2.21.

Method B: Broadcasting over entire area with no preparation of the soil; area traversed only once.

By sowing 100,000 seed to the acre, the cost for Norway spruce was \$1.65, for yellow pine \$12.75, and for Douglas fir \$4.35. With 150,000 seed to the acre, the cost for Norway spruce was \$2.10, for yellow pine \$18.75, and for Douglas fir \$6.15. With 200,000 seed to the acre, the cost for Norway spruce was \$2.55, for yellow pine \$24.75, and for Douglas fir \$7.95. With 250,000 seed to the acre, the cost for Norway spruce was \$3, for yellow pine \$30.75, and for Douglas fir \$9.75. If the area had been traversed twice instead of once, the cost in each instance would have been increased approximately 29 cents per acre.

CLASS III SITE.

Method A: Seed spots 12 inches in diameter, spaced 6 by 6 feet; ground loosened from 3 to 4 inches in depth; seed covered; soil not tamped.

With from 10 to 15 seed per spot, it cost per acre for Norway spruce \$2.20, for yellow pine \$3.89, and for Douglas fir \$2.59. With

from 20 to 30 seed per spot, it cost per acre for Norway spruce \$2.31, for yellow pine \$4.69, and for Douglas fir \$3.09.

Method B: Complete broadcasting with no preparation of the ground.

By sowing 100,000 seed to the acre the cost for Norway spruce was \$1.85, for yellow pine \$12.95, and for Douglas fir \$4.55. With 150,000 seed to the acre the cost for Norway spruce was \$2.30, for yellow pine \$18.95, and for Douglas fir \$6.35. With 200,000 seed to the acre the cost for Norway spruce was \$2.75, for yellow pine \$24.95, and for Douglas fir \$8.15. With 250,000 seed to the acre the cost for Norway spruce was \$3.20, for yellow pine \$30.95, and for Douglas fir \$9.95.

An estimate is here given of the cost of sowing western white pine and red pine by Method A on Class III site, and by Method B on Class II site. The figures given are exclusive of the cost of the seed and are based upon the same cost given in the preceding examples for the same methods and sites. The cost of western white pine seed is placed at \$4.50 per pound and that of red pine at \$9 per pound, figures which are conservative for the calendar year 1910. If the cost of sowing yellow pine, the most expensive of the three species previously mentioned, is compared with that for sowing western white pine and red pine, it will be seen that on an average it costs approximately one-third more to broadcast the two last species than the first, and a fraction over one-fifth more if the sowing is done according to Method A in the Class III site.

By sowing from 10 to 15 seed per spot in accordance with Method A, Class III site, it would cost per acre for western white pine \$4.62 and for red pine \$4.66. By the same method, but with from 20 to 30 seed per spot, it would cost per acre for western white pine \$6.95 and for red pine \$7.04.

By broadcasting 100,000 seed per acre in accordance with Method B, Class II site, it would cost for western white pine \$16.82 and for red pine \$17.13. With 150,000 seed to the acre it would cost for western white pine \$24.87 and for red pine \$25.32. With 200,000 seed to the acre it would cost for western white pine \$32.88 and for red pine \$33.51. With 250,000 seed to the acre it would cost for western white pine \$40.94 and for red pine \$41.70. The above estimates are based upon the assumption that the area was traversed only once. If it was traversed twice the cost would be increased approximately 29 cents per acre.

INSTANCES OF SUCCESSFUL DIRECT SEEDING.

OLYMPIC NATIONAL FOREST, WASHINGTON.

An area, known as the Soleduck Burn, comprising 6,000 acres within the Olympic National Forest, was burned over in the summer of 1907 by a very severe fire, which destroyed the entire original

stand of old Douglas fir and hemlock, as well as the humus, and badly baked the soil. The area is largely high bench land, at an altitude of approximately 1,000 feet. In December, 1909, the burned area was sown broadcast to Douglas fir. While two years had elapsed since the fire, the brush cover was not excessively heavy. It was lightest on the steep slopes. On more level land there was a considerable quantity of dead fern which had grown up during the preceding summer, while moss was beginning to form a layer over the ground. The soil is a dry, gravelly clay, which dries out rapidly in the summer on account of southern exposure, but the site is an excellent one for Douglas fir, as indicated by the down and fire-killed timber. Rains are heavy between September and May, but there is little precipitation during the summer. Sowing was done with Douglas fir seed collected in the fall in the region immediately south of Tacoma, Wash., and coated with red lead. Seed was broadcasted over the entire area, 4 pounds, or 170,000 seed, to the acre. Sowing was done by hand, each man casting a distance of 22 feet—11 to the right and 11 to the left. The cost in labor of sowing the seed was 47 cents per acre, which, together with 4 pounds of seed at \$1.50 per pound, made a total cost per acre of \$6.47. The germination per cent of the seed sown, according to the test made in the Forest Service laboratory at Washington, was 77 per cent.

In August, 1910, sample areas laid off in representative portions of the seeded area showed a stand of seedlings ranging from 4,000 to 5,000 to the acre. These had withstood the dry season fairly well, though some were a little yellowish. On an average they were about an inch high. The thickest stand was found on fine, loose soil, somewhat sandy in character, near the stream bed, where other vegetation was not thick. Here on 1 square rod were counted as many as 35 seedlings. On the bench land seedlings ran about 30 to the square rod, while on the steep slopes the results were as good if not a little better.

OREGON NATIONAL FOREST, OREGON.

What is known as the Latrouelle Prairie tract is situated at the headwaters of the Bull Run River, in the Oregon National Forest. The area was formerly occupied by a rather heavy stand of Douglas fir and western white pine. A severe fire occurred several years ago, killing off the entire stand and burning off the humus completely. Some of the fire-killed trees still stand and others have fallen and lie scattered over the area. The tract sown is a portion of the bench land on the southwest slope of Shell Rock Mountain. At the northern end it slopes gently downward to a second bench 15 feet below, and at the southern end it descends abruptly with a slope of over 60 per cent. The soil is a clayey loam mixed with large quantities of

loose rock. On all but the steep slopes, where erosion has taken place, exposing the rocks, a light soil with some humus covers the area. At the time of sowing the ground cover which had come in since the fire, consisting chiefly of dead fern and fireweed of the previous season's growth, was rather dense in the northern end of the tract, while elsewhere were patches of moss. The ground cover was thickest, of course, on the steep south slope.

The region is one of heavy precipitation, except during July, August, and September. The tract was sown to Douglas fir on November 10, 1909, and sowing was done in three strips, in one of which the seed was sown broadcast, $5\frac{1}{2}$ pounds per acre; in the second, $3\frac{1}{2}$ pounds per acre; while in the third the seed-spot method was used. In this last the spots were spaced 7 by 7 feet and from 15 to 20 seeds sown per spot, or at the rate of four-ninths of a pound per acre. There was about a foot of fresh snow on the unfrozen ground, and in preparing the spots this was dug away so as to expose the mineral soil on a spot of about 1 foot in diameter. The seed was covered to a depth of about one-quarter of an inch. In August, 1910, after the dry season was practically over, four sample areas, each about 6 feet square, were measured in the first strip. In one 12 seedlings were found, in another 13, in a third 19, and in a fourth 32. The average number of seedlings per acre was therefore 22,990. No count was made on the second strip, but on the third strip, which was sown with the seed-spot method, 25 spots were examined. The maximum number of seedlings in any one spot was 4, while in 7 of the 25 spots examined no seedlings had come up. For all 25 spots the average number of seedlings was 1.72, making an average per acre of 1,527. In comparing these results with those from the strip broadcasted, it should be remembered that only four-fifths of a pound, or 19,000 seed, were sown to the acre. Its per cent of germination, as determined in the Forest Service testing laboratory, was 77.

SIUSLAW NATIONAL FOREST, OREGON.

In the fall of 1909 and the spring of 1910 a tract of over 1,300 acres on the Siuslaw National Forest was sown to Douglas fir. This tract, which is a part of a large burned district, was once heavily timbered with Douglas fir, Sitka spruce, and western red cedar. The topography is typical of the entire Coast Range, being moderately rough, but not excessively rugged. The soil, except in numerous spots where shale predominates, is a reddish loam. The severe fires of the past have apparently removed much of the original plant food contained in the soil, since numerous attempts to farm the land have proved unsuccessful. The tract, which is known as the Mount Hebo sowing area, has an altitude of about 1,500 feet.

The fall sowing in 1909 was done in several different ways. After the dead fern which covered most of the area had been burned off, a portion of the tract was sown broadcast. Another portion was broadcasted in strips, some of which had been previously harrowed; while in others seed was forced into the soil by tree tops hauled over

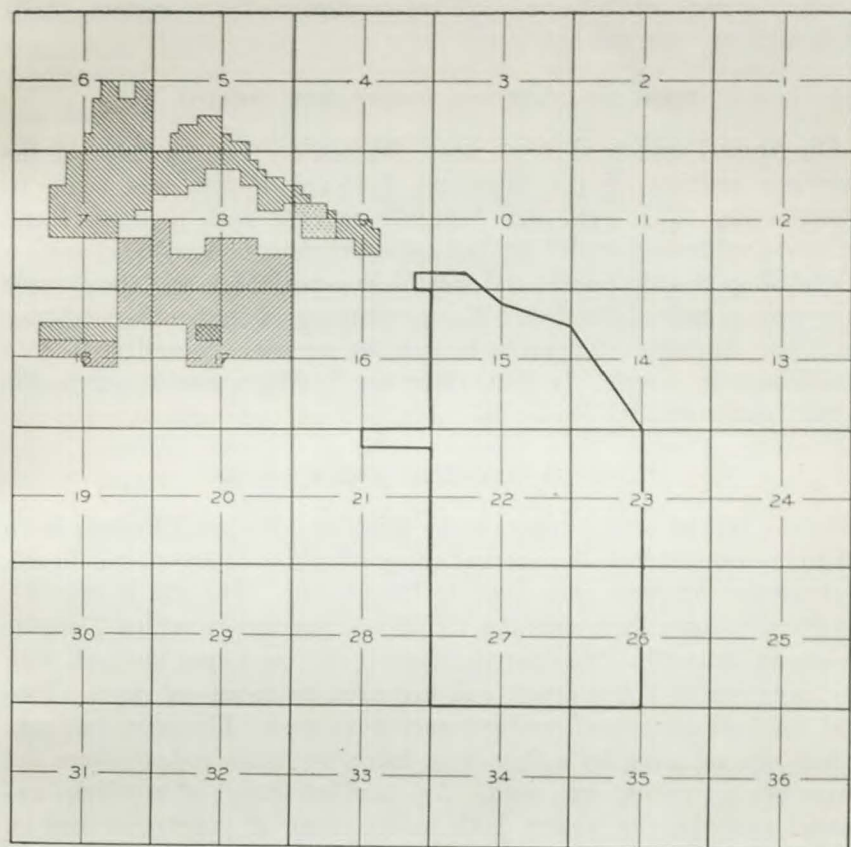


FIG. 4.—Mount Hebo, showing areas of Stuslaw National Forest, T. 4 S., R. 9 W., Willamette meridian, Oregon.

them. Still another portion of the tract was sown by the seed-spot method. An inspection made during August, 1910, showed that the best results were obtained where the seed was sown in seed spots. There the seed came up uniformly and there was scarcely a spot which

did not contain at least one seedling, while on areas which had been harrowed or brushed the seedlings came up in groups and not uniformly.

Twenty-five hundred additional acres of the Mount Hebo area were sown during the winter of 1910-11 to Douglas fir, Sitka spruce, and Norway spruce, while some small tracts were seeded to walnut, shell-bark hickory, and red oak.

MANZANO NATIONAL FOREST, NEW MEXICO.

On April 7 and 8, 1910, an area situated on the east slope of the northern portion of the Manzano National Forest was sown to Douglas fir. This area was formerly covered with a heavy stand of Douglas fir and white fir, but repeated fires had reduced it to a waste of scrub oak, brush, and worthless aspen thickets. Its altitude is approximately 7,500 feet. The sowing was done by the seed-spot method. An inspection made late in the summer showed from 1 to 6 seedlings in a spot. In fact, there was hardly a blank spot in the whole tract sown.

MINIDOKA NATIONAL FOREST, IDAHO.

In the fall of 1909 a tract on the Minidoka National Forest, at an altitude of 6,250 feet, the natural cover of which is aspen, sagebrush, and patches of grass, was sown to Douglas fir. The soil is gravelly loam, with some lime, and the vicinity is not one in which Douglas fir grows naturally. Sowing was done by the seed-spot method, with the spots spaced 5 feet apart, and prepared by means of rakes. Two and one-half pounds of seed per acre were used. The tract was protected against stock by a four-wire fence, but since rodents were not numerous no poison was used. An excellent stand of seedlings appeared early in the spring, both under cover of vegetation and on open grassy areas. On July 12, 1910, however, after a drought of approximately four months, an inspection showed that the seedlings not protected by cover of vegetation had disappeared. Under the aspen and chaparral, however, the effect of the drought was not so marked, and the seedlings there made a good showing. On October 14, 1910, another inspection showed an average of 7 or 8 living plants on each spot protected by aspen.

UINTA NATIONAL FOREST, UTAH.

* On this Forest most of the burned areas originally occupied by coniferous stands come up to scrubby stands of aspen. The site selected for direct seeding was at an altitude of 7,500 feet on a southern slope within the lodgepole-pine belt. The soil was a clayey loam,

with a clay subsoil. Douglas fir and lodgepole pine in equal quantities were the species sown. The sowing was done on July 7, 1909, by the seed-spot method, with the spots prepared by raking and spaced 5 by 5 feet apart. The ground cover, aside from the aspen, consisted of a moderately dense growth of weeds. At the time the sowing was done the area was fairly moist. On September 28, 1909, inspection showed that there were from 5 to 20 seedlings on practically every spot, all in good condition. No poison was used, since the tract is some distance from heavy timber, and the seed in only six or eight spots had been eaten by mice or chipmunks.

BITTERROOT NATIONAL FOREST, MONTANA.

The area seeded on the Forest consisted of logged-over land, formerly bearing a stand of yellow pine on the knolls and Douglas fir and grand fir and Engelmann spruce in three gulches, which were prominent features of the sowing area. Skidding out the logs had left the soil well broken, especially in the bottoms. The object in sowing this area was to ascertain whether broadcast sowing would give practical results, if done directly after logging operations. White pine and Engelmann spruce seed were sown in mixture on the area in October, 1909. It had been the intention to sow as much as possible on the area by means of corn planters, but the brush and duff on the ground prevented their use, and it was therefore necessary to broadcast. Three and two-fifths pounds of seed were used to the acre, about four-fifths of which was white pine and one-fifth Engelmann spruce. Inspection of the tract in July and October, 1910, showed large numbers of thrifty trees. The spruce had done better than the white pine, especially in moist situations where the soil had been protected by brush, logs, etc. On some of these areas an average of 12 spruce seedlings per square foot was found. White-pine seedlings were scattered over the area, but were most numerous on the higher land. The fact that these white-pine seedlings were living and thrifty in October, after one of the driest summers in years, is significant of the possibilities for direct seeding in similar situations.

WHITE RIVER NATIONAL FOREST, COLORADO.

On May 8, 1908, a tract within the White River National Forest, having a northern exposure, and at an altitude of about 8,100 feet, was sown to Engelmann spruce and lodgepole pine at the rate of 1 pound of the former and $1\frac{1}{2}$ pounds of the latter per acre. The soil was a moist, mineralized clay overlying sandstone. The ground cover was made up of buck brush and bunch grass, with some ashes and humus. The fire which destroyed the original timber occurred about 35 years ago.

The seed was sown broadcast, one-half on the snow and the other half on bare ground, without in any way preparing the soil. The weather at the time of sowing was clear, warm, and dry. Inspection made July 17, 1909, showed an average of 43,000 Engelmann spruce and 10,000 lodgepole pine seedlings per acre. A recent inspection showed that the drought during the summer of 1910, combined with winter killing, had killed a large number of the seedlings, but there still remained per acre an average of 10,000 Engelmann spruce and 4,000 lodgepole pine.

BLACK HILLS NATIONAL FOREST, SOUTH DAKOTA.

On July 2, 1905, 38 pounds of yellow-pine seed, collected in 1903 on the Pecos National Forest, New Mexico, were broadcasted on bare ground in the center of what is known as the Elk Creek burn of 1893. The area is on nearly level ground, sloping gently to the south, and the soil is a shallow loam with schist outcropping. At the time of the sowing there was a scanty ground cover and a scattering growth of aspen. About 30 per cent of the area, however, was bare. On October 30, 1909, an inspection showed an average of 24,700 seedlings per acre, all of which were making a good growth.

SEQUOIA NATIONAL FOREST, CALIFORNIA.

In November, 1909, a tract within the Sequoia National Forest, known as the Shake Camp experimental area, situated in Tulare County, in the west slope of the Sierra Nevadas, was sown to Douglas fir. The tract was near the top of a low ridge, with north and east exposures, at an altitude of approximately 4,100 feet. The soil was dark, sandy loam. An open stand of black oak (*Quercus emoryi*) covered the area and the ground cover was of grass and filaree. Sowing was done by the seed-spot method, the spots being from 12 to 16 inches square, and spaced 8 by 8 feet. Each spot was cleared and the soil stirred to a depth of from 4 to 6 inches. The seed was covered one-half inch deep. Six pounds of seed were used per acre, some of the seed being coated with red lead. An examination on May 29, 1910, showed that rodents had taken most of the untreated seed. In that portion of the area sown with treated seed the majority of the seed spots contained seedlings, some as many as 10, but with an average of 4 or 5.

TRINITY NATIONAL FOREST, CALIFORNIA.

An area on this Forest burned over many years ago, and since then rather heavily grazed, was sown in December, 1909, and in March, 1910. The tract has a hot southern exposure and an eleva-

tion between 1,000 and 1,300 feet. The soil is light and dry, but suitable for the production of yellow pine, as evidenced by scatter-

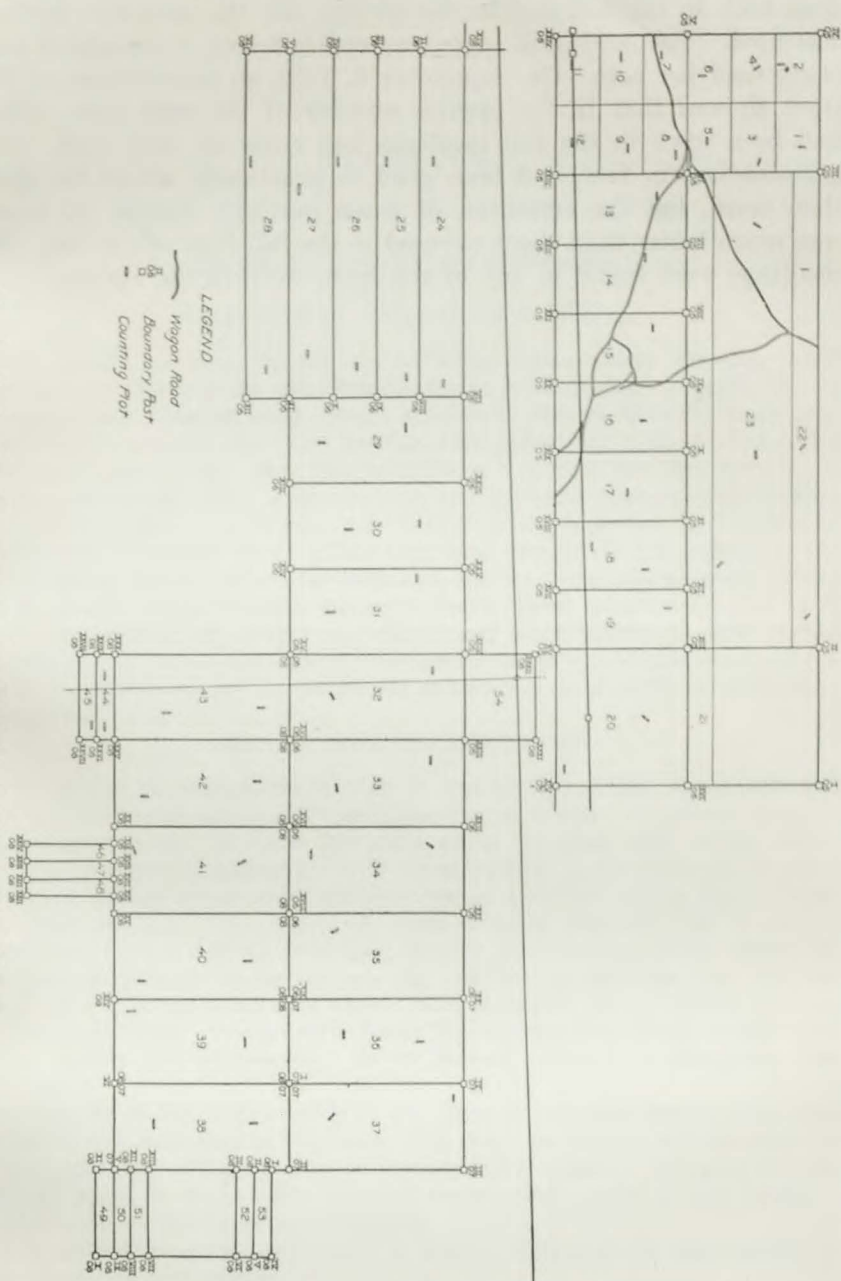


FIG. 5.—Custer Peak Experimental Area No. 1, Black Hills National Forest.

ing thrifty trees of this species growing on the hillside. The lower part of this area is partially covered with scrub oak and madroña, while the upper end extends into a small, open park. It is an oak-

brush area, typical of extensive stretches of country in the Coast Range. Small grass-grown openings are common. The sowing was done both in the fall and in the spring, and the seed-spot method was used. The sowing in spots was rather heavy, 6 pounds of seed being used per acre. On September 3, 1910, an examination of the tract showed that in the greater number of the seed spots which had been sown in the fall seedlings had come up very well. The germination, in fact, had been good in practically all of the spots then sown, but the condition of those partially shaded by brush was much better than those exposed to the full heat of the sun. No seedlings were found in any of the spots sown in the spring.

APPENDIX.

NOTES ON INDIVIDUAL SPECIES.

AUSTRIAN PINE (*Pinus laricis austriaca*).

This species has been planted in the United States, chiefly for ornamental purposes and shelter belts, from Massachusetts to California. It yields strong, coarse-grained, resinous wood, useful principally for all sorts of rough construction. It is hardy and rapid growing when young, but in the United States seems to be short lived.¹ It is able to thrive on very poor, thin, dry soils, but it requires warm and sunny situations and will not grow where the atmosphere is misty and damp. In Europe it is considered the best tree for planting in shallow, hot, limestone soils. It has been used extensively for planting in the Karst region, Austria, where the climate is similar to the southwestern United States, much of the planting being on nearly bare, calcareous rock. It is reproduced abroad by using 2-year-old nursery stock planted in pure stands. Experiments in direct seeding with this species in the yellow-pine region of the Rocky Mountains suggest the possibility of its being successfully established by this method.

BIGTREE (*Sequoia washingtonia*).

The bigtree is remarkable in that it reaches the largest dimensions and attains the greatest age of any tree in the United States. Its natural range is limited to a stretch of about 260 miles along the west slope of the Sierra Nevadas in central California. It is found usually at an elevation of about 6,500 feet, though it sometimes grows as low as 4,800 feet and as high as 8,400 feet above the sea. The climate in which it grows indicates that it may be extensively used in reforestation work outside of its natural range, where the precipitation exceeds 20 inches annually and the temperature does not fall below 12° F. It can stand long winters with abundant snow, provided they are comparatively mild. It requires a moist, well-drained soil, plenty of light, and grows rapidly and persistently. In its natural range it is practically free from fungi.

Bigtree bears some seed every year, but years of abundant seeding occur only at intervals of from four to five years. The cones are mature and the seed ripe by the latter part of July and fall in October and November. The seed is much eaten by squirrels, which begin to cut off the cones in August as soon as ripe—a point to be considered in seed collecting.

It is believed that the bigtree will do well in certain of the coast forests of both California and Oregon.

¹ For information concerning liability to insect attack of this and other trees mentioned in the Appendix, see Bureau of Entomology Bulletin 83, Part 1, and other publications of that bureau dealing with forest insects. Further information may be obtained upon application to the Bureau of Entomology.

BLACK WALNUT (*Juglans nigra*).

This tree produces valuable lumber. The growth is rapid, but satisfactory results could hardly be expected on any but rather good soils. The species is comparatively free from attacks by insects and fungi. The nuts are produced abundantly and are easily gathered and stored. It is usually advisable to plant the nuts directly in the field in seed spots, because of the long taproot developed by the seedlings. Being an intolerant tree, it should be grown in mixture with other hardwoods, such as red oak. Black walnut seedling should be confined to the more protected situations, where the soil is deep and fresh. It is native to the National Forests of Arkansas, and is apparently adapted to certain parts of Washington, Oregon, and Idaho.

CORK OAK (*Quercus suber*).

Cork oak is of considerable commercial importance, especially near the Mediterranean Sea in France, Spain, and Algiers. It is from this tree that all the cork of commerce is made. None is produced in the United States. It can be safely said, judging from its distribution in Europe and elsewhere, that cork oak is adapted for planting in the United States wherever the climate meets approximately the following conditions: Minimum temperature, 21° to 25° F.; maximum temperature, 104° F.; minimum precipitation, 20 inches.

The climate of some of the Southern States, especially Florida, Texas, and portions of California, meet the above requirements. Calcareous soils are believed to be favorable to the best growth of cork oak. There are a number of specimens of the tree growing in the South from seed imported and distributed by the United States Department of Agriculture about 1860. At Chico, Cal., the tree has done well. In reforestation work the acorns may be dibbled in where the trees are to grow, or may be sown in a nursery and the seedlings set out when 1 year old. The acorns of the best variety are difficult to secure, as the cork industry is jealously guarded. Experiments indicate that the Chocatawhatchee, Ocala, Monterey, Cleveland, Santa Barbara, Angeles, Sierra, and Sequoia National Forests are suitable for the production of cork oak.

DOUGLAS FIR (*Pseudotsuga taxifolia*).

Douglas fir, next to western yellow pine, has the widest range of any of the important commercial trees of the United States, and more lumber is cut from it than from any other species. Its very rapid growth, ease of reproduction, adaptability to a wide range of sites, and the commercial value of its wood assure it a permanent place as the leading timber tree of the West and as one well adapted for reforestation work.

Silviculturally there are two distinct forms of Douglas fir, one of which inhabits the regions west of the Cascades and Sierra Nevada Mountains, while the other grows throughout the Rocky Mountain region. For planting, the coast form is superior to the mountain form in every respect and should always be used where the climate is favorable.

Douglas fir generally bears seed abundantly every two years, and good seed can be collected at reasonable cost. Broadcast or seed-spot sowing will probably be the best method of artificially propagating the species, but in certain regions, particularly in the Rocky Mountains, planting of 1 or 2 year old nursery stock, spaced 4 to 6 feet apart each way, is advisable. The seed must come into immediate contact with the mineral soil, otherwise germination can not be expected. The tree is not exacting in regard to depth or quality of the soil, provided the subsoil is deep and porous and the drainage is good.

Douglas fir should be used even more extensively than at present in the forestation work of the Service and its seed should be gathered in greater quantity than that of any other species.

ENGELMANN SPRUCE (*Picea engelmanni*).

This is a characteristic tree of the Rocky Mountains, usually growing at high altitudes. It is of secondary importance as a lumber tree, but produces fairly heavy stands, and, like most trees of the Rockies, grows rather slowly. It is of great importance in the protection of watersheds, and for that reason is one of the trees which should be used in reforestation throughout the Rocky Mountain States.

Seed of Engelmann spruce, while not easily obtained, can be secured in moderate quantities, and since the seeds are very small and of fair fertility, only a small quantity is needed per acre in sowing. Much larger quantities of Engelmann spruce seed should be gathered by the Forest Service in the future than has been done in the past, and sowing should be conducted in the numerous Engelmann spruce burns, particularly in Colorado, Wyoming, Utah, and along the main range in Montana.

EUCALYPTS.

This genus is valuable because of its rapid growth and consequent early production of firewood and more valuable products. The trees, however, grow only in regions free from severe frosts, such as parts of California, Arizona, and Florida. They do well on a great variety of soils, and they are practically free from attack from fungi.

Eucalyptus seedlings, when young, are very tender, and require care in the nursery. They are set out in pure stands when a few months old. Natural reproduction, noted even in young plantations, suggests the desirability of thorough experiments in direct seeding.

Trees of this genus are recommended for planting in the limited areas suitable for their growth in the Cleveland, Angeles, Santa Barbara, Monterey, and Ocala National Forests.

EUROPEAN LARCH (*Larix europaea*).

European larch is a desirable tree for commercial planting in the United States. It is a rapid grower and produces heavy, hard, strong, flexible, and very durable wood. It has been successfully grown in the United States from New England to South Dakota, and south to Kansas and Virginia, to which general region it is adapted for commercial planting. It does well in eastern Washington also. European larch is rather fastidious in regard to soil, requiring one that is deep, light, fresh, and well drained, and does not flourish in swamps as does the American larch. It may be established by direct seeding, or by planting 2-year-old seedlings or transplants from the nursery. It should be sown or planted in mixture with other species rather than pure, in a proportion of one larch to three or more trees of other species, the trees being spaced 4 to 6 feet apart each way.

European larch should be used in a limited way in reforestation work in the Superior National Forest and in the Forests of central Idaho.

THE HICKORIES.

The hickories are very valuable because of the great strength and toughness of the wood. For vehicle manufacture and tool and implement handles the wood is unequalled. The planting of the better species is therefore highly de-

sirable. Their growth is moderately rapid, and they do well on a variety of soils. They are subject to insect attacks,¹ and for this reason it is well to plant them in mixture with other species. If they are to grow to a considerable age they should be underplanted with a tolerant species, such as sugar maple or beech.

The nuts are borne abundantly and are easy to collect. The young seedlings develop a long taproot, so that except where there is great danger from rodents the nuts should be field planted direct in seed spots.

LODGEPOLE PINE (*Pinus murrayana*).

This is the most typical tree of the Rocky Mountains. It reaches only a small size, but grows rather rapidly, considering the climate, and produces dense stands of straight trees admirably adapted for many purposes. Lodgepole pine forms a valuable protection forest at moderate and high elevations from southern California to the Canadian boundary. It bears moderate quantities of seed, and the cones are persistent, often remaining unopened, with the seed fertile, for years. It is possible, therefore, to obtain the cones in large quantities. Opening the cones and extracting the seed has so far proved very difficult and expensive, bringing the cost of the seed up to about \$4 a pound. Individual seeds are very small, running about 100,000 to the pound. The germination per cent is fairly high, so that but 2 or 3 pounds of seed per acre is required even in broadcast sowing; where the seed-spot method is used less will suffice. Sowing has proved successful in freshly burned-over areas, and it is believed that the species can be reproduced extensively by direct seeding where conditions are favorable. Lodgepole pine seed should be obtained in much greater quantities in the future than in the past.

NORWAY SPRUCE (*Picea excelsa*).

This tree should be a very valuable substitute for red spruce in the making of pulp, since it grows much faster and produces equally good fiber. It is adapted to the northern United States. Its growth is rapid, and it produces dense stands, which can be used either for lumber or for pulp. It is also useful for reforesting watersheds. It grows on a great variety of soils, and does best where there is plenty of rainfall. Fungi are not a serious menace.

Norway spruce may be propagated by sowing in seed spots or by planting young trees. It grows well in pure stands, but may be used in mixture with white pine or other similar species. It is recommended for reforestation on fresh soils throughout the northern United States, and especially in the Superior National Forest, Minnesota, and the northern Rocky Mountains.

RED OAK (*Quercus rubra*).

Red oak is one of the most desirable species of hardwoods for reforestation purposes. It is a rapid grower, long-lived, attains large dimensions, and produces a heavy, hard, coarse-grained, strong, and moderately durable wood. Its natural range is from Nova Scotia to eastern Kansas and south to northern Georgia. In this general region it can be successfully planted, preferably on porous, sandy, or gravelly clay soils. It can be grown in pure stands, but will also do well in mixture with sugar maple, white elm, chestnut, white pine, hickories, and with other oaks.

Red oak can best be propagated by sowing the acorns directly on the area to be planted, since nursery-grown seedlings develop a large taproot and are difficult to transplant. The acorns should be planted in well-prepared seed

¹ Yearbook, Department of Agriculture, 1903, p. 314.

spots, spaced 4 to 6 feet each way, three or four acorns in each spot, and covered with about 1 to 1½ inches of earth.

Red oak is a fairly prolific seeder, and the acorns can be easily collected from the ground and by shaking the tree after several severe frosts in the fall. They are quite bitter and are not as a rule relished by squirrels. Like most other oaks, red oak is not subject to disease, and plantations require little or no care after establishment.

Red oak is being used quite extensively in reforestation work in the Arkansas and Ozark National Forests, and merits thorough trial in a number of the Forests of Idaho, Washington, and Oregon.

RED PINE (*Pinus resinosa*).

Red pine approaches the white pine in value, the wood of the two species being somewhat alike. Its growth, too, is rapid. It produces fairly dense stands of timber of good quality, even on soils too poor for white pine. The seed is borne very sparingly and is difficult to collect, so that it is too expensive to use for direct seeding. As a rule, however, it will not be necessary to raise the seedlings in a nursery, since where the tree occurs naturally there is a plentiful supply of wild seedlings which it is easy to collect. Red pine is very resistant to fire after it has reached the sapling stage. It should be planted extensively in the Lake States, especially on the Michigan, Marquette, and Minnesota National Forests.

SCOTCH PINE (*Pinus sylvestris*).

This species is one of the most important commercial trees abroad, and has been found of some value in the northern United States. Its growth is rapid, especially during the first 20 years. It produces moderately dense stands of good lumber, and will grow on a variety of soils. Fungi do not damage it to any considerable extent. Seed should be obtained from Scandinavia or Russia. Seedlings are easy to raise, though seed may be sown in seed spots. The species may be planted pure or in mixture with red pine, white pine, or European larch. Scotch pine will grow in the Lake States and throughout the yellow-pine region of the West. Its great hardiness and the low cost of the seed suggest its use in reforestation.

SITKA SPRUCE (*Picea sitchensis*).

Sitka spruce is a large and important tree of the Pacific coast. Its range extends from northwestern California to Alaska, but it is not found very far inland. It occurs upon only a few of the National Forests, but within its range is an exceedingly important species. It grows very rapidly, produces good material, and is almost free from damage by insects and fungus.¹ Because of the dense shade produced and the heavy rainfall in the region of its range, it is unusually free from fire.

The seed of Sitka spruce is easily obtained during seed years. Direct seeding appears, therefore, to be the logical method for its artificial production. The National Forests upon which it should be used extensively are the Siuslaw, the Olympic, the Washington, and the Snoqualmie.

SUGAR PINE (*Pinus lambertiana*).

Sugar pine attains the largest dimensions of any of the white-pine species. It is a rapid grower, and produces wood of the same character and high value as eastern white pine. It does not often grow in pure stands and forms usually about 20 per cent of the stand in which it occurs. As long as there is

¹ The tree may be attacked by the Sitka spruce weevil and by defoliating insects. (See Bureau of Entomology Bul. 21, p. 918.)

sufficient atmospheric moisture, sugar pine is not exacting in its soil requirements. It is found mostly on well-drained slopes, especially north and east ones.

Sugar pine produces seed in moderate abundance about every five years, but produces some seed every year. The seeds are large, have a rather low germinating per cent, and are greedily eaten by birds and squirrels.

Broadcasting is not feasible, since at least 80,000 seeds should be sown per acre, and as there are but 2,400 seeds per pound and a pound costs 85 cents, the cost per acre of sowing broadcast, including labor, would be in excess of \$30. Seed-spot sowing is more promising. The planting of nursery-grown stock rather than direct seeding seems advisable in propagating the species. It should be grown in mixture with other species rather than pure. In reforestation work on the National Forests in California and southern Oregon this desirable tree should be extensively used.

WESTERN LARCH (*Larix occidentalis*).

Western larch is an important timber tree of the Northwest, from western Montana to the eastern slope of the Cascade Mountains in Oregon and Washington. The seed is small and rather difficult to obtain, but on account of the great number of seeds per pound, even though they are not particularly vigorous, seeding is believed to be practicable. It should be sown on fairly good forest soil where there is little or no shade. The tree does well in mixture with Douglas fir.

Western larch should be used to a moderate degree in reforestation work in appropriate localities on the National Forests within its natural range.

WESTERN WHITE PINE (*Pinus monticola*).

This is a very valuable timber tree in certain portions of the Northwest. It grows rapidly, produces heavy stands of valuable timber, and may be grown on rough, steep mountain sides. Seed of this species is not easily obtained as a general rule, so that it is necessary to do some planting. In nurseries the seed comes up unevenly, and therefore requires treatment, such as stratification every winter, or soaking before being sown.

Western white pine should be used extensively in reforestation work on the National Forests of northwestern Montana at altitudes of from 3,800 to 5,500 feet, throughout northern Idaho at similar altitudes, and in western Washington below 4,500 feet. Every effort should be made to obtain large quantities of seed.

WESTERN RED CEDAR (*Thuja plicata*).

This is an important commercial tree of the Northwest, contributing as it does 60 per cent of all the shingles annually produced in the United States. It is highly prized for posts, poles, and for cooperage, being very light and durable. It is a tree of comparatively slow but persistent growth, is long lived, and attains very large dimensions. The tree is much affected by a fungus causing heart rot. It requires abundant soil moisture and grows best in a humid climate. It grows in dense stands, sometimes pure, but generally in mixture with other species. Seed is produced abundantly nearly every year, and may be collected at a cost of \$2 per pound. The seed ripens in the summer, has a high rate of germination, and usually germinates the same fall. The vitality of the seed is greatly reduced by storing even for one year. Because of its slow growth, western red cedar should be used only to a limited extent in reforestation work in the Northwest. It may be propagated by broadcasting the seed on moist situations, otherwise seedlings should be grown in the nursery and transplanted.

WESTERN YELLOW PINE (*Pinus ponderosa*).

Western yellow pine is one of the largest and most valuable of the pines. Its range is the widest of any of the commercial trees of the western United States, and includes the dry foothills and lower slopes of the Rocky Mountains, the high plateaus of Arizona and New Mexico, the east slope of the Cascades, and appropriate situations throughout California. Yellow pine is not a fast-growing tree, except in favorable situations in the Pacific Coast States. It produces rather open stands of good timber, is hardy, and will grow on a wide diversity of soils.

Since the seed is produced in abundance and the long taproot makes seedlings somewhat difficult to transplant, it is often advisable to sow the seed direct. Yellow pine, as a rule, produces light stands of timber, grows in places where it is relatively of small importance for stream regulation, and where, owing to lack of moisture, artificial forestation is difficult. It is felt, therefore, that the species should be used less extensively than at present in planting and sowing work, at least until the unproductive areas capable of supporting rapid-growing trees producing heavy stands, and which are of importance in stream protection, have been forested.

WHITE OAK (*Quercus alba*).

White oak produces very valuable lumber. So great is the economic value of this wood that the available supply is being rapidly exhausted. Its growth is slow but persistent, and trees attain great age. White oak grows best on rich, moist, well-drained loam, or clay loam, and prefers protected situations, but can also maintain itself fairly well on poor soils and in exposed situations. In starting a plantation of white oak it usually will be advisable to sow the acorns directly on the area to be planted rather than to use nursery stock, because of the taproot and the difficulty and expense involved in transplanting the seedlings. The acorns should preferably be sown in well-cultivated seed spots, 4 to 6 feet apart each way, with three or four acorns in each spot, covered with about 1 inch of earth. The planting should be done in the fall, unless there is danger of the acorns being eaten by squirrels and other rodents, in which case the acorns should be stored for winter by stratifying them in a box of moist sand and planted the following spring.

White oak seeds prolifically nearly every year, and the acorns can be gathered from the ground without much difficulty in the fall. Plantations after being made require little or no care. This species is well adapted to the Ozark and Arkansas National Forests.

WHITE PINE (*Pinus strobus*).

The value of white pine is universally recognized. It grows rapidly and produces heavy stands on a great variety of soils, though it is in some danger from attack by insects and fungi. Seed crops occur at intervals of from three to five years, when seed may be gathered at a cost of from \$1.50 to \$4 per pound. Seedlings are easily raised and planted in the field. This method of reforestation has so far been more satisfactory than broadcasting or sowing in seed spots, but direct seeding has also been successful. It can be grown in pure stands or mixed with other trees, such as red oak or red pine, depending upon soil and situation.

White pine should be used extensively in reforestation work in the Lake States and possibly in western Montana and northern Idaho.